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16. Abstract <p>This report describes two experiments evaluating format changes on instrument approach plates (IAPs). The study used a simple chart reading task to assess information transfer in IAPs.</p> <p>The first experiment addressed different methods of displaying approach course information. Three methods were evaluated: font size, bold type, and reverse video. Bold type had a negligible effect on chart reading performance. Both boxing and reverse video improved the speed with which items could be found and or identified on the chart. The use of font size as a method for presenting information was clear; a larger font size, 12 point, was more effective for presenting the inbound heading, than a smaller, 9 point size.</p> <p>The second experiment examined the effectiveness of four different layouts for displaying radio frequencies. Three of the four layouts were similar to those found in existing charts published by NOAA, Jeppesen Sanderson, Inc. and the Canadian Department of Energy, Mines and Resources. The fourth layout was a two column layout, not currently found on existing charts. The two layouts analogous to the formats used by NOAA and Jeppesen Sanderson, Inc. resulted in similar performance. Performance in the two column layout and boxed layout was superior to performance in the NOAA and Jeppesen Sanderson, Inc. formats.</p>					
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## PREFACE

This report describes two experiments evaluating the efficacy of different formatting methods in the transfer of information on instrument approach plates. Experiment one evaluated the use of highlighting and font size for presenting the final approach course. Experiment two evaluated four layouts for presenting radio frequencies.

This report was prepared by the Operator Performance and Safety Analysis Division of the Office of Research and Analysis at the **Volpe** National Transportation Systems Center (**VNTSC**). The report was prepared for the Aviation Research and Development Office of the Federal Aviation Administration.

The report was completed under the direction of **VNTSC** Program manager **M. Stephen Huntley Jr.** The research and report preparation was the responsibility of Jordan **Multer**, Margaret Warner, and Robert **Disario**.

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# METRIC/ ENGLISH CONVERSION FACTORS

## ENGLISH TO METRIC

### LENGTH (APPROXIMATE)

1 inch (in) = **2.5** centimeters (cm)  
 1 foot (ft) = **30** centimeters (cm)  
 1 yard (yd) = **0.9** meter(m)  
 1 mile (mi) = **1.6** kilometers (km)

### AREA (APPROXIMATE)

1 square inch (sq in, in<sup>2</sup>) = **6.5** square centimeters (cm<sup>2</sup>)  
 1 square foot (sq ft, ft<sup>2</sup>) = **0.09** square meter (m<sup>2</sup>)  
 1 square yard (sq yd, yd<sup>2</sup>) = **0.8** square meter (m<sup>2</sup>)  
 1 square mile (sq mi, mi<sup>2</sup>) = **2.6** square kilometers (km<sup>2</sup>)  
 1 acre = **0.4** hectares (he) = **4,000** square meters (m<sup>2</sup>)

### MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = **28** grams (gr)  
 1 pound (lb) = **.45** kilogram (kg)  
 1 short ton = **2,000** pounds (lb) = **0.9** tonne (t)

### VOLUME (APPROXIMATE)

1 teaspoon (tsp) = **5** milliliters (ml)  
 1 tablespoon (tbsp) = **15** milliliters (ml)  
 1 fluid ounce (fl oz) = **30** milliliters (ml)  
 1 cup (c) = **0.24** liter (l)  
 1 pint (pt) = **0.47** liter (l)  
 1 quart (qt) = **0.96** liter (l)  
 1 gallon (gal) = **3.8** liters (l)  
 1 cubic foot (cu ft, ft<sup>3</sup>) = **0.03** cubic meter (m<sup>3</sup>)  
 1 cubic yard (cu yd, yd<sup>3</sup>) = **0.76** cubic meter (m<sup>3</sup>)

### TEMPERATURE (EXACT)

$$[(x - 32) (5/9)] ^\circ\text{F} = y ^\circ\text{C}$$

## METRIC TO ENGLISH

### LENGTH (APPROXIMATE)

1 millimeter (mm) = **0.04** inch (in)  
 1 centimeter (cm) = **0.4** inch (in)  
 1 meter(m) = **3.3** feet (ft)  
 1 meter(m) = **1.1** yards (yd)  
 1 kilometer (km) = **0.6** mile (mi)

### AREA (APPROXIMATE)

1 square centimeter (cm<sup>2</sup>) = **0.16** square inch (sq in, in<sup>2</sup>)  
 1 square meter (m<sup>2</sup>) = **1.2** square yards (sq yd, yd<sup>2</sup>)  
 1 square kilometer (km<sup>2</sup>) = **0.4** square mile (sq mi, mi<sup>2</sup>)  
 1 hectare (he) = **10,000** square meters (m<sup>2</sup>) = **2.5** acres

### MASS -WEIGHT (APPROXIMATE)

1 gram (gr) = **0.036** ounce (oz)  
 1 kilogram (kg) = **2.2** pounds (lb)  
 1 tonne (t) = **1,000** kilograms (kg) = **1.1** short tons

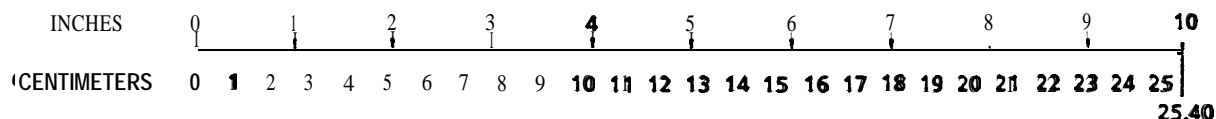
### VOLUME (APPROXIMATE)

1 milliliter (ml) = **0.03** fluid ounce (fl oz)  
 1 liter (l) = **2.1** pints (pt)  
 1 liter (l) = **1.06** quarts (qt)  
 1 liter (l) = **0.26** gallon (gal)  
 1 cubic meter (m<sup>3</sup>) = **36** cubic feet (cu ft, ft<sup>3</sup>)  
 1 cubic meter (m<sup>3</sup>) = **1.3** cubic yards (cu yd, yd<sup>3</sup>)

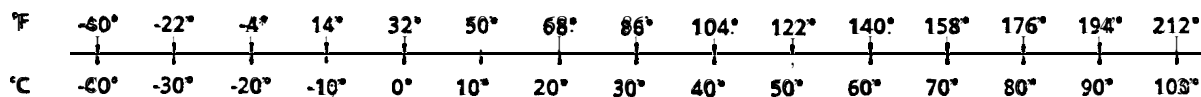
### TEMPERATURE (EXACT)

$$[(9/5)y + 32] ^\circ\text{C} = x ^\circ\text{F}$$

## QUICK INCH-CENTIMETER LENGTH CONVERSION



## QUICK FAHRENHEIT/CELSIUS TEMPERATURE CONVERSION



For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price \$2.50. SD Catalog No. C13 10 266.

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## EXECUTIVE SUMMARY

Currently, there is no research examining the problems of Instrument Approach Plate (**IAP**) design. As a result, designers do not have performance data for evaluating the effects of design changes on instrument approach plates nor do they have comprehensive chart design guidelines for helping to make these decisions. Performance data and guidelines are **needed** to systematically incorporate concern for human factors into chart designs. At the request of the FAA's Office of Research and Development (**ARD-210**), the Operator Performance and Safety Division of the **Volpe** National Transportation Systems Center is addressing this issue. The two experiments discussed in this report are part of a research program to address this need. These experiments represent the first in a series of experiments that will address formatting issues relevant to both paper and electronic charts.

The first experiment addressed different methods of displaying approach course information. The **IAP** procedure is a high workload condition that requires the pilot to divide his attention among several activities that include: monitoring the cockpit instruments, communicating with Air Traffic Control, and looking out the window for traffic. Therefore, it is essential that information needed from the **IAP** be retrieved as quickly as possible. Designers have a number of techniques at their disposal for highlighting approach course information on **IAPs**; however, none of these methods have been evaluated to determine their effect on chart reading performance. This experiment evaluated the effect of two font sizes, bold type, and reverse video on chart reading performance.

Twenty pilots were shown a series of fictitious **IAPs** and asked to find and identify the approach course as quickly as possible. The charts differed in the font size of the heading (9 point or 12 point) and whether the heading was displayed in plain text, bold, or reverse video. Performance was measured by recording the time required to identify the inbound heading and the number of identification errors.

This experiment demonstrated that there was an interactive relationship between font size and highlighting method. The relationship between font size and highlighting method depended upon the particular highlighting method. In the case of bold type and boxing, font size and highlighting contributed additively to performance. There was a negative relationship between font size and response time; as font size increased, response time decreased. In the case of reverse video, this relationship was not observed. Response time did not vary with changes in font size.

Different highlighting cues: bold type, boxing, and reverse video exhibited varying degrees of effectiveness. Bold type had a negligible effect on chart reading performance. Although bold type was preferred to no highlighting at all, it was not an effective method for highlighting the critical items, like the inbound heading. Both boxing and reverse video improved the speed with which items could be found and or identified on the chart. While reverse video was as effective as boxing, more research is needed to determine under what conditions reverse video might be used. The attention getting properties of reverse video may also detract from chart reading performance when looking for an item not displayed in reverse video.



The use of font size as a method for presenting information was clear in this experiment. The larger font size, **12** point, was more effective for presenting critical items, like the inbound heading, than the smaller, 9 point, size in a field of 9 point items.

For chart designers, the data from this experiment lead to the following recommendations: Displaying the approach course track in **12** point increases readability and increases search effectiveness in a field of 9 point text. Boxing and reverse video (white on black background) significantly reduce the time necessary to locate and read digits identifying the approach course track and so are both effective methods of presentation. Bold type is not an effective method for highlighting the approach course track.

The second experiment examined the effects of layout on the chart reading performance of radio frequencies. Spatial layout is an important factor influencing the readability of **IAPs**. In the case of text there are several spacing attributes that influence readability, including spacing between letters, spacing between words, and spacing between lines. However, it is not simply the physical distance between two objects that affects clarity; the structure of the space separating text also plays a role (e.g., justification of margins). The presentation of radio frequencies on **IAPs** differs between chart publishers. The purpose of this experiment was to evaluate the effectiveness of different layouts for displaying radio frequencies.

Four layouts were evaluated in this experiment. In layout **1**, the frequency was located directly under the facility name as in the NOAA charts. In layout **2**, the frequency was located directly to the right of the facility name as in the **Jeppesen** Sanderson charts. In layout **3**, the facility names and frequencies were placed in two left justified columns separated by **0.15** inches. The facility name was located to the left of the frequency. In layout **4**, each facility name and frequency pair was enclosed in a box across the top of the plan view as in the Canadian Energy, Mines and Resources charts. The experiment evaluated the speed and accuracy with which pilots could find and identify frequencies using the four layouts.

To measure chart reading performance, **20** pilots were given a simple chart reading task. The pilots were shown a series of fictitious **IAPs** and asked to find and identify the target frequency (either approach control or tower frequency) as quickly as possible. The charts differed in the layout of the facility name and frequency. Performance was measured by recording the response time and number of identification errors.

The results of this experiment indicated that spatial layout affects the speed with which **IAPs** can be read. The two layouts designed to test formats similar to those used in NOAA and **Jeppesen** Sanderson Inc. charts resulted in similar performance. Neither layout was more effective than the other. These layouts presented facility names and frequencies in one column with the frequency either to the right or beneath the associated name. Performance in the two column layout and boxed layout was superior to performance in both of the one column formats. Both of these layouts used space to actively organize the placement of text. The readability of radio frequencies in the **IAPs** will be increased by locating each frequency in a separate box with boxes organized in a row across the top of the plan view section. Alternatively, displaying radio frequencies in a two column format with facility names in one

left justified column and frequencies in another left justified column will also improve readability, by reducing the time needed to locate a particular frequency.



## 1. BACKGROUND

Instrument approach procedures describe the FAA approved flight path that must be flown, under Instrument Flight Rules (**IFR**), to land an aircraft safely. Since World War II, the information needed to fly the instrument approach procedure has been presented graphically on an Instrument Approach Plate (**IAP**). The **IAP** serves as a quick reference guide for the pilot to find and/or verify information necessary to fly the approach. These charts display the approach procedure graphically from a bird's eye (plan) view and a profile view, as well as displaying communication frequencies, landing minima, and on some charts, an airport diagram.

Flying an instrument approach is a high-workload task that requires the pilot to make many complex decisions within a brief period of time. The Instrument approach plate represents a vehicle for reducing the reliance on memory by providing information critical to the successful completion of the approach procedure.

As the national air space has increased in complexity, so too has the demand for information. Current chart designs have evolved over the years as publishers modified charts in response to changes in the national air space and user requests. Chart publishers have accommodated additional demands for information where possible, yet the size of the paper charts has remained constant (approximately **8.3** by **5.8** inches). This size conforms to the standard recommended by the International Civil Aviation Organization (**1985**). The additional information has increased the amount of visual clutter. Chart publishers modify their chart design in an effort to make them easier to use, but problems still exist. While a large percentage of pilots report that they are satisfied with the approach charts currently in use (**Cox & Conner, 1988**), a large number report problems.

Current instrument approach charts are criticized for being cluttered, difficult to read, and lacking necessary information. Respondents of the **Cox and Conner (1988)** survey report that it takes too long to search for specific pieces of information. It should not be surprising that the charts have become cluttered, given the large amount of information packed into such a small space. The optimal print density for a page is **40** percent (Dancheck, **1976**). The remaining **60** percent of the page should be white space. Visual inspection shows that many instrument approach plates (**IAPs**) clearly exceed this recommendation (see Appendix A for sample charts).

Chart publishers have modified their chart formats in an effort to make them easier to use, however, they have not systematically addressed human factors considerations. Instrument approach charts are complex and a simple format change may have unintended consequences. Interactions between different elements on the charts are often unknown to the chart designer. A change in one element of the design may result in consequences that were not anticipated by the chart designer. For example, increasing the font size of the landing minima may increase the legibility of the numbers, but may also increase clutter by decreasing the amount of white space. In addition, design guidelines on the format, coding and legibility of text are often specific to the type of material on which the research was

based (**Hopkin** and Taylor, **1979**). Thus, design recommendations applicable to manuals and prose may not always apply to charts. Currently, there is no research examining the problems of **IAP** design. As a result, designers do not have performance data for evaluating the effects of design changes on instrument approach plates nor do they have comprehensive chart design guidelines for helping to make these decisions. Performance data and guidelines are needed to systematically incorporate concern for human factors into chart designs.

The two experiments discussed in this report are part of a research program to address this need. The program will develop methods for evaluating information transfer from instrument approach plates and systematically assess different aspects of chart formatting on readability. These experiments represent the first in a series of experiments that will address formatting issues relevant to both paper and electronic charts. This study evaluated a simple visual search task for assessing information transfer in **IAPs**. Several performance measures were collected to evaluate this method. Speed and accuracy provided objective measures of performance while questionnaires indicated performance subjectively.

Experiment 1 assesses the efficacy of several methods for displaying the approach course track. Experiment 2 evaluates how layout affects the speed and accuracy with which communication frequencies can be found.

## 2. EXPERIMENT ONE

### AN EVALUATION OF METHODS FOR DISPLAYING APPROACH COURSE INFORMATION

#### 2.1 INTRODUCTION

The instrument approach procedure is a high-workload situation that requires the pilot to perform a multitude of tasks. The pilot's attention is divided among many activities including monitoring the cockpit instruments, communicating with Air Traffic Control and looking out the cockpit window for traffic. Therefore, it is essential that information needed from the instrument approach plate be retrieved as quickly as possible. In the only recent large scale survey (**Cox and Conner, 1988**) of problems associated with instrument approach plates (**IAPs**), respondents complained that too much time was required to **find** information on the chart. A key issue for chart designers, therefore, is how to facilitate the visual search process to minimize the amount of time it takes to find a particular item and identify it.

Chart designers use a variety of methods to direct attention. In presenting information, different symbols and text are portrayed with different sizes, weights (e.g., line thickness), and contrasts (e.g., percent of gray scale) relative to their importance. Items which are least important are displayed in the minimum size, weight, or contrast that is considered legible. Items of greater importance are displayed in progressively larger sizes, weights, or contrasts (**Keates, 1989**).

The application of presentation techniques differs between publishers. Different chart publishers may use the same technique to emphasize different portions of the chart. For example, one National Oceanic and Atmospheric Administration (NOAA) chart displays the time from the Final Approach Fix (**FAF**) to the Missed Approach (MAP) in plain text, and the chart headings in **bold**, while the **Jeppesen** Sanderson chart does the opposite. In other cases, publishers highlight information using the same techniques, giving the same relative weight to an item, but differ in the absolute weighting. For example, **Jeppesen** Sanderson charts highlight the inbound heading using **12** point type with the surrounding text in **10** point type, while NOAA charts highlight the inbound heading using 9 point type with the surrounding text in 7 point type.

In addition to font size and **bolding**, publishers also use boxing and reverse **video** (white on black) to highlight information in various ways. Is one method better than another? No one has established which highlighting methods are effective in the context of instrument approach plates and under what conditions. The purpose of this experiment was to assess the effectiveness of several commonly used techniques (font size, **bolding**, boxing, and reverse video) for highlighting information on **IAPs**.

The results of past research addressing four methods of highlighting (**bolding**, boxing, reverse video, and font size) are mixed and may not be directly applicable to aeronautical charts (**Hopkin and Taylor, 1979**). These four methods will be discussed next, along with the questions to be addressed in this experiment.

## **2.1.1 Bold Type**

The use of bold type is common in **IAPs**. However Phillips, **Noyes**, and **Audley (1977)** report that bold type is no more legible than normal type weight when used in street maps and should be avoided because it increases clutter. Search times did not differ significantly between the two type weights (plain text and bold). This research does not indicate whether bold type might be an effective method for highlighting infrequently displayed items. In the Phillips et al. **(1977)** experiment, bold and plain typefaces were not mixed. However bold type might improve search time in a background of plain text where the bold typeface might increase the salience of the item to be found. The current experiment assesses whether bold type is an effective method by comparing bold type on the inbound heading to plain text.

### **2.1.2 Boxing and Reverse Video**

Research evaluating the effects of boxing and reverse video as methods of highlighting have met with mixed results. Bridgeman and Wade **(1956)** found that boxing improves reading performance. Observers exhibited better recognition when letters were boxed than not boxed. **Gomberg (1985)**, however, reports that both boxing and reverse video can slow performance as compared to no highlighting. Subjects searching for a single target digit in a background of distractor digits were slower to find a target in the highlighted condition than in the no highlighted condition. Fisher and Tan **(1989)** attributed these results to masking by the highlighting attribute. In their view, the box or area in reverse video delays the identification process. Bridgeman and Wade **(1956)** found the same effect in their boxing experiment, as well. As the size of letters within a box increased, subjects displayed poorer letter recognition. Fisher and Tan **(1989)** tested their hypothesis using reverse video as one of the methods of highlighting. They asked subjects to search for target digits in a background of four distractor digits. In some trials, the target was highlighted. In others, the target was not highlighted. Search time was found to be faster when the target was not highlighted than when highlighted by reverse video.

These findings suggest that boxing and reverse video may actually impair performance under the same conditions. However, the observed behavior may be sufficiently different from chart reading behavior that different results may be observed under conditions typically found while reading **IAPs**. The previously described experiments used a small number of alphanumeric **distractors** and the experimental materials were arranged in an orderly fashion. Given that search time and identification time are two components of total response time, search time may comprise a smaller portion of total response time than identification in the previous experiments. By contrast, reading a typical **IAP** requires a random search with many **distractors**. In this situation, the search time component may account for a significant portion of the total response time. If so, the attention-getting attributes of boxing and reverse video may outweigh the negative effects of masking observed in Fisher and Tan **(1989)** and Bridgeman and Wade **(1956)**. The present experiment tested this hypothesis. Specifically, it was hypothesized that in the context of **IAPs** response time for boxing and reverse video presentation of the inbound heading would be faster than no highlighting.

### 2.1.3 Font Size

Font size is another attribute used for indicating differences in relative importance. As a method for directing attention, font size may contribute positively to both the visual search and identification components of the observer's response. If so, larger font sizes with their greater legibility should be easier to read than small font sizes. Phillips, **Noyes** and **Audley**, (1977) report differences in search time as a function of font size. Using street maps, Phillips et al. (1977) found that search was faster for the 8 point type than the 6 point type.

On **IAPs**, font size is used to differentiate the inbound heading from other headings in the plan view. Currently the inbound heading is displayed on NOAA charts in 9 point type while the other headings are displayed in 8 point type. **Jeppesen** Sanderson charts display the inbound heading in **12** point type, two points larger than the other headings. Examples of both types are illustrated in Appendix A. Although the inbound heading is larger than other headings for both charts, the small difference may only marginally decrease search time. A larger difference in font size between the inbound heading and other headings may decrease search time further. This experiment will evaluate the effect of using a larger font size to highlight the inbound heading.

In summary, this experiment will test the following hypotheses:

1. **Bolding** is an effective highlighting attribute. Response time for **bolded** items will be shorter than for plain text.
2. Boxing and reverse video are more effective than plain text for displaying the inbound heading. In chart reading, visual search may comprise a larger component of total response time than the identification component. In this situation, highlighting attributes, boxing and reverse video, which decrease search time, will result in faster response time than no highlighting.
3. Larger fonts are read faster than smaller fonts and decrease response time.



## **2.2 GENERAL METHODOLOGY**

The following discussion covers those aspects of the methodology that the two experiments share in common. Those aspects that were unique to each experiment are described in separate sections. The methodology unique to the highlighting experiment follows this section. The methodology unique to the layout experiment is described in the following report describing the effects of layout on **IAP** readability.

### **2.2.1 Subjects**

Subjects were recruited through the Airline Pilots Association (**ALPA**) and through notices posted at the **Volpe** National Transportation Systems Center (**VNTSC**) and the Massachusetts Institute of Technology (MIT). **VNTSC** employees were given an account number to charge the time they spent in the study. All other subjects were paid **\$50**.

Twenty pilots participated in this study. Nine of the pilots were rated for Instrument Flight Rules (**IFR**) and **11** were rated for Visual Flight Rules (**VFR**). The pilots ranged in age from **19** to **61** with a median age of **31**. Flight experience ranged from **60** hours to **15,000** hours, with the **VFR** rated pilots having a median of **120** flight hours and the **IFR** rated pilots having a median of **600** flight hours.

### **2.2.2 Apparatus**

The subject sat **20** inches (**50.8** cm) from a rear view projection screen mounted on a desk directly in front of him. A floor mounted chin rest was used to maintain the constant viewing distance from the screen; the vertical height of the chin rest and chair were adjusted to fit each subject. Stimuli were projected onto the screen using a **Gerbrands** Model **1178 3-Field Projection Tachistoscope** (T-scope) located behind the rear projection screen. The **T-scope** was mounted on a formica base and seated on a cart **38"** from the floor. The **Gerbrands** T-scope consisted of 3 Kodak **Ektagraphic** Model **IIIB** slide projectors with internally mounted **Gerbrands** shutters and a shutter drive control console. Three mirrors direct each of the projector beams to the same area on the rear projection screen. The three slide projectors displayed different stimulus materials. One projector displayed the fixation point, a second projector displayed sample stimuli, and a third projector displayed the experimental stimuli. A button box, located on the desk in front of the projection screen, was used by the subject to indicate that the stimulus was identified. An IBM compatible **286** computer controlled the timing of the **tachistoscope** and recorded the signals from the button box.

### **2.2.3 Procedures**

Two experiments were conducted during a single session lasting between one and three hours. For each experiment, it took approximately **20** minutes to collect the data. Subjects were run one at a time. The time varied widely due to the length of the discussions with

interested subjects. All experiments were conducted in the same room using the same apparatus and protocol.

Upon arrival, the subject was greeted and briefly introduced to the procedures. The subject was told that there were two experiments, each of which was designed to evaluate different aspects of **IAP** design. For each experiment, the subject's task was to search for a target on the **IAP**, specified by the experimenter in advance. Each experiment consisted of several blocks of experimental trials.

A trial consisted of presenting a fixation point followed by an experimental stimulus. The subject focused on a fixation point located in the center of the plan view for **1.5** seconds. Immediately following the termination of the fixation point, an experimental chart was presented. When the experimental chart was displayed, the subject searched for the target. The subject was instructed to press the button box and say aloud his response when he identified the target. The button press ended the presentation of the experimental stimulus and marked the end of the trial. There was a **1.5-second** inter-trial interval. The number of trials per block and the number of blocks per experiment varied between experiments. The script used to deliver the general instructions is found in Appendix **B**.

After discussing the procedures and answering any questions the subject was given a consent form to read and sign. When the consent form was signed, the subject filled out a questionnaire requesting biographical information and familiarity with **IAPs** (see Appendix **C**). Next, the subject was given twenty practice trials to become familiar with the apparatus and the procedure. Following completion of the practice trials, the subject began the individual experiments.

The experiments were always run in the same order so that any order effects (e.g., fatigue, learning) would be constant across experiments. The first experiment assessed the use of line width and font size as cues for discriminating different categories of information in **IAPs**. All information regarding this experiment can be found in a separate report (**Chandra, 1990**). The second experiment assessed the effect of layout on the readability of communication frequencies. The third experiment assessed the efficacy of various graphic techniques for highlighting the inbound heading.

After completing all three experiments, the subject was given three questionnaires, one for each of the experiments as shown in Appendix **C**.

#### **2.2.4 Performance Measures**

Response time and number of errors were the two primary performance measures. Response time was measured by the computer from the point at which the stimulus was presented on the screen to the point at which the subject pressed the button box. Number of errors was measured by recording the verbal identification of the target stimulus and tabulating the number of correct and incorrect responses.

### **2.2.5 Questionnaires**

A questionnaire regarding the subject's pilot experience, certification, and other characteristics was given to all subjects before beginning the experiments (see Appendix C). At the conclusion of the three experiments, subjects filled out questionnaires on each of the experiments. For the highlighting experiment, the questionnaire asked subjects to rank their performance and preference for the different methods of highlighting the inbound heading. For the layout experiment, the questionnaire asked subjects to rank their performance and preference for each layout.

## 2.3 METHODOLOGY FOR EVALUATING HIGHLIGHTING AND FONT SIZE

### 2.3.1 Design

Two levels of font size, 9 and **12**, were used to present the inbound heading. Four methods of highlighting the approach heading were chosen: a control condition with no highlighting (none), bold, boxed, and reverse video. Each condition is illustrated in Appendix **D**.

A mixed three-factor design with one between-subjects and two within-subjects factors, was used. (Shown in Table **1**.) The between-subjects factor was pilot rating with two levels, Instrument Flight Rules (**IFR**) and Visual Flight Rules (**VFR**). The two within-subjects factors represented changes in font size and highlighting. (Yes or no).

**TABLE 1. HIGHLIGHTING EXPERIMENTAL DESIGN**

Font Size	9				12			
Type of Highlighting	None	Bold	Box	Rvrse video	None	Bold	Box	Rvrse video
Pilot Type								

Trials were blocked into eight groups of five trials. Each block of five trials represents one combination of font size and highlighting, as shown in Appendix **D**. Presentation of the stimuli were randomized within blocks as well as between blocks. All combinations of the two within subject variables were tested.

### 2.3.2 Stimulus Construction

The experimental stimuli were modeled after the NOAA instrument approach plates. The stimuli were created from scratch on an Apple Macintosh computer using the graphics program Canvas by **Deneba** Systems. The charts were photographed and mounted in pin registered slide mounts.

The experimental and sample charts, modeled after the NOAA format, were constructed from six chart templates. **Each** template was modified by changing the font size (**2** levels) or method of highlighting (**4** levels) to create eight unique chart combinations. Two sets of stimuli were created for a total of **96** charts (**8\*6\*2=96**).

The inbound heading located in the profile view was erased to prevent the subject from finding the target in areas other than the plan view. No other changes were made to the design of the charts.

### **2.3.3 Procedures**

The subject was told that he would see a series of instrument approach plates and instructed to search for the inbound heading as quickly and accurately as possible. Prior to the start of the experiment, the experimenter explained that the inbound heading was changed in several ways and shown an example of the **16** ways the inbound heading was formatted. The script for instructing the subject is shown in Appendix **B**.

Many **VFR** pilots and all **IFR** pilots understood what to search for and required no training. However, some **VFR** pilots were unfamiliar with **IAPs** and were given training in locating the inbound heading. **VFR** pilots who required training were shown a series of NOAA charts (**10-20**) and asked to name the inbound heading. A subject had to identify the inbound heading correctly 8 times before proceeding to the experimental task.

The stimuli were shown in **16** blocks of 5 trials. At the start of each new block, the subject viewed a sample chart for five seconds to become familiar with the chart format to follow. Each block was followed by a brief rest period. For the first 3 blocks, the subject received a **15-second** rest. Following the fourth block the subject received a rest of **1-2** minutes. The experimenter entered the laboratory during this extended rest period to determine if the subject was fatigued or uncomfortable and needed to readjust the chair or chin rest position. This pattern of 3 short rest periods followed by a longer rest period repeated itself every 4 blocks.

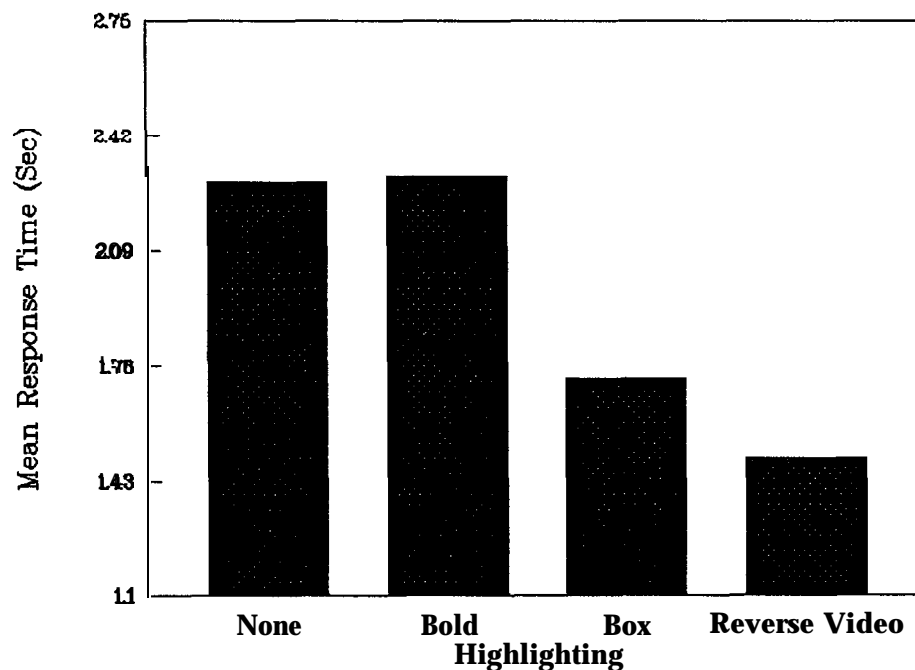
## 2.4 RESULTS AND DISCUSSION

### 2.4.1 Pilot Rating

An analysis of **variance (ANOVA)** was performed to determine whether there were differences in response time as a function of flight experience and to learn whether experience influenced performance. **The ANOVA** was not statistically significant  $F(1,18) = 0.14, p > .71$ , indicating that experience did not reliably influence how the two groups performed. The remaining analyses were performed on data collapsed across pilot rating.

### 2.4.2 Highlighting and Font Size

Figure 1 shows the mean response time by highlighting method. The bold type condition displayed the longest mean response time (**2.3 sec.**) followed by no highlighting (**2.28**), boxed (**1.73 sec.**), and reverse video (**1.5 sec.**). An **ANOVA** reveals that there is a main effect for highlighting method  $F(3,57) = 34.30, p < .0001$ . Performance in the bold type condition was worse than in the no highlighting condition, although this result was not statistically significant. By contrast, both the boxed and reverse video condition gave results that were significantly different from those for the no highlighting condition, as indicated by a test of pair-wise comparisons:  $CR_{\text{box}}(p < .05, 4, 57) = .258$ ;  $CR_{\text{rev}}(p < .05, 4, 57) = .258$ . Although the response time was faster in the reverse video condition than in the boxing condition, the difference was not statistically significant.



**FIGURE 1. EFFECT OF HIGHLIGHTING METHOD ON MEAN RESPONSE TIME**

Examining the highlighting effects alone, it is clear that bold type is not an effective method in the conditions represented in the current study. Bold type did not improve performance compared to no highlighting, as was hypothesized. By contrast both boxing and reverse video proved to be effective methods of highlighting. Performance in these two conditions was much better than when there was no highlighting.

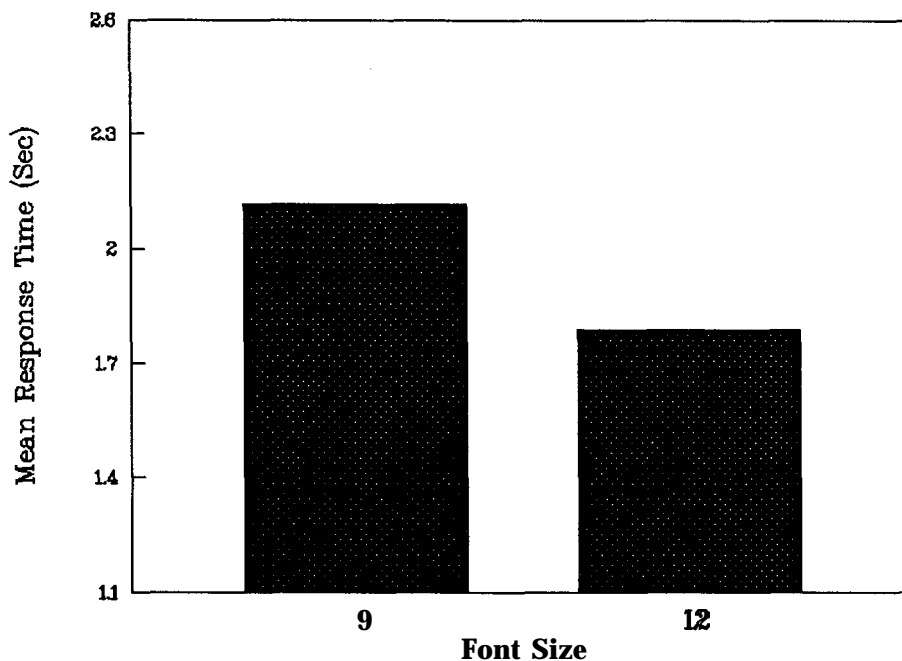
The results of an analysis of subject preferences differed somewhat from the objective data. As part of the experiment, subjects were asked to rank their preferences for the different highlighting conditions as well as how well they thought they performed using a particular type of highlighting. Subjects ranked their preferences for highlighting in the following order, from most preferred to least: boxed, reverse video, bold, and no highlighting. Subjects preferred the bold type to the no highlighted condition; they also preferred the boxed condition over reverse video. A Friedman two way analysis of variance was significant for this ranking:  $\chi^2(3,19) = 33.72, p < .001$ . When asked to rank the highlighting methods according to how quickly they were able to find information, they ranked the reverse video condition first, followed by the boxed, bold, and no highlighting condition. Again, this ranking was statistically significant:  $\chi^2(3,19) = 42.72, p < .001$ .

The discrepancy between how the subjects thought they performed on boxed and reverse video and their preferences for these two methods merit additional consideration. The pilots' preference for the boxed condition over reverse video reflects a number of concerns. The subjects were concerned about how reverse video might be implemented on the **IAPs**. Some pilots reported that the attention getting properties that make reverse video a powerful cue when searching for an item can be distracting when looking for an item that is not highlighted. If reverse video were used in many places it might be increasingly difficult to find other items. Other subjects thought it was more difficult to identify the heading, once it was found. Although the subjects did not mention it, they may have preferred the boxed condition because they are accustomed to seeing boxed text on **IAPs** (i.e., the navigation boxes).

Figure 2 illustrates the relationship between font size and response time. Performance was faster for the larger font size. Subjects spent an average of **1.79** seconds searching for the inbound heading displayed in **12** point and **2.11** seconds searching for headings in 9 point, a difference of **0.32** seconds. This is consistent with subjects' preferences. All the subjects preferred the inbound heading displayed in **12** point type over the headings displayed in 9 point. Examining font size collapsed across highlighting conditions, an **ANOVA** shows a main effect for font size:  $F(1,19) = 37.67, p < .0001$ . The performance differences between the two font sizes may be attributable to two factors. First, the **12** point type was larger and thus easier to detect. Second, the inbound heading the subject searched for was surrounded by text in 8 and 9 point type. Since the inbound heading was the only item in the plan view that was printed in **12** point, it was more salient. The inbound heading printed in 9 point was more difficult to detect in a field of similarly sized items. These data support the use of **12** point for the inbound heading.

Figure 3 and Table 2 show the mean response time for the three methods of highlighting and the control condition, by font size. Response time for each highlighting condition differs by font size. An analysis of variance conducted on the subject's response times found a

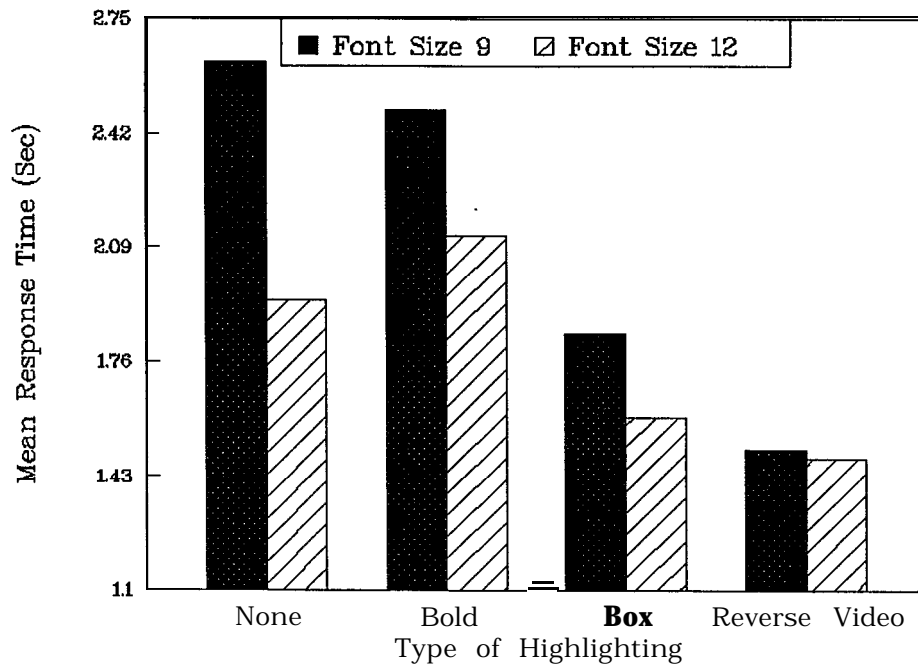
significant two way interaction between font size and highlighting method:  $F(3,57) = 57, p < .0002$ . Figure 3 shows that the largest differences in performance by font size **occurred** in the no highlighting condition. Here, subjects take **0.69** seconds less to **find** the target in the **12** point condition than in the 9 point condition, a statistically significant difference as indicated by a **Student-Newman-Keuls** test of pair-wise comparisons  $CR_{\alpha-k} (p < .05, 8, 133) = 0.363$ . For two of the three highlighting conditions, bold and boxing, performance is also better in the **12** point condition. A **Student-Newman-Keuls** test-of pair-wise comparisons indicates that these differences are also statistically significant: bold,  $CR_{\alpha-k} (p < .05, 6, 133) = 0.341$ ; and boxed,  $CR_{\alpha-k} (p < .05, 2, 133) = 0.233$ . However, the performance differences between the two font sizes diminish to **0.37** seconds for bold, **0.25** seconds for boxed. For the reverse video condition, the differences between font size conditions diminish to **0.03** seconds. This difference is not statistically significant.



**FIGURE 2. EFFECT OF FONT SIZE ON MEAN RESPONSE TIME**

The foregoing analysis suggests that font size and highlighting do not operate independently of each other. Font size appears to contribute more to headings identified with some highlighting methods (bold and boxing) than others. Font size is not as effective a cue when reverse video is used as when bold type, boxing, or no highlighting is used. The attention getting properties of reverse video may be so powerful that they overwhelm the effects of font size. These results suggest that when using reverse video to highlight text, it is not necessary to also use font sizes above **12** point to increase chart reading performance. For the other types of highlighting examined in this study, font size combined with highlighting to increase chart reading performance.





**FIGURE 3. EFFECT OF HIGHLIGHTING METHOD AND FONT SIZE ON MEAN RESPONSE TIME**

**TABLE 2. EFFECT OF HIGHLIGHTING METHOD AND FONT SIZE ON MEAN RESPONSE TIME (SEC)**

Font Size	Highlighting			
	None	Bold	Box	Reverse Video
9	<b>2.63</b>	<b>2.49</b>	<b>1.85</b>	<b>1.51</b>
12	<b>1.94</b>	<b>2.12</b>	<b>1.60</b>	<b>1.48</b>

## 2.5 CONCLUSIONS

The purpose of this experiment was to evaluate the effectiveness of several stimulus cues for highlighting information on instrument approach plates (**IAPs**). The experiment found the following relationships.

The effect of the highlighting cues: bold type, boxing, and reverse video exhibited varying degrees of effectiveness. Bold type had a negligible effect on chart reading performance. Although bold type was preferred to no highlighting at all, it was not an effective method for highlighting the critical items, like the inbound heading. Both boxing and reverse video improved the speed with which items could be found and or identified on the chart. While reverse video was as effective as boxing more research is needed to determine under what conditions reverse video might be used. The attention getting properties of reverse video may also detract from chart reading performance when the reader is looking for an item not displayed in reverse video. Research is necessary to determine the extent to which reverse video may impair performance, and to develop strategies for minimizing or avoiding this potential problem.

The use of font size as a method for improving readability and/or highlighting information was clear in this experiment. The larger font size, **12** point, was more effective for highlighting critical items, like the inbound heading, than the smaller, 9 point, size in a field of 9 point items.

The experiment demonstrated that there was an interactive relationship between the two stimulus cues, font size and highlighting method. The relationship between font size and highlighting method depends upon the particular highlighting method. In the case of bold type and boxing, font size and highlighting contribute additively to performance. There was a negative relationship between font size and response time; as font size increased, response time decreased. In the case of reverse video, this relationship was not observed. Response time did not vary with changes in font size. Reverse video may be such an effective cue that it overwhelms any effects due to font size.

For chart designers, the data from this experiment lead to the following recommendations:

Displaying the approach course track in **12** point increases readability and increases search effectiveness in a field of 9 point text.

Boxing and reverse video (white on black background) are both effective methods for highlighting the approach course track.

Bold type is not an effective method for highlighting the approach course track. However, this recommendation should not lead to the conclusion that bold type is inappropriate method for formatting instrument approach plates. Bold type may be an effective formatting technique for other information on the chart.

### 3. EXPERIMENT TWO

#### AN EVALUATION OF METHODS FOR PRESENTING RADIO FREQUENCIES ON INSTRUMENT APPROACH PLATES

##### 3.1 INTRODUCTION

For instrument approach plates (**IAPs**), spatial layout is important to readability. The spacing of information serves as a cue for perceptually grouping information (Hartley, **1981**; Wright, **1977**). The grouping of information is affected by the space that separates an object from its surroundings. Space helps to define the boundaries of an object as well as to separate multiple objects from each other.

In the case of text, there are several spacing attributes that influence readability, including spacing between letters, spacing between words, and spacing between lines. For example in reading a word, the inter-letter spacing is an important factor in determining the clarity of a word. If the letters are spaced too closely, the individual letters are difficult to discriminate and the word may not be legible. If the letters are spaced too far apart, the letters are not perceived as “belonging together” and the object is not interpreted as a word.

However, it is not simply the physical distance between two objects that affects clarity, the structure of the space separating text also plays a role. Letters or numbers separated by a structured space enable the reader to develop spatial expectancies that may not develop when spacing is unstructured (**Tullis, 1981**). For example, one method for structuring the space between text is through justification, in which the left or right edge of the text column is aligned in the vertical dimension. This alignment creates a boundary separating the text from the background and has the same effect as drawing a vertical line to delineate text.

One area on the **IAP** that has not been studied, but where spatial layout may contribute to its ease of use, is the presentation of radio frequencies. During the course of flight, the pilot communicates with a variety of Air Traffic Control (**ATC**) facilities. The high workload conditions present during the approach require that the pilot be able to find the radio frequency for contacting **ATC** as quickly as possible. The speed with which a particular frequency can be located is partially dependent on how that information is laid out. The presentation of radio frequencies on **IAPs** has been implemented in different ways by the chart publishers, but the effectiveness of those layouts has never been tested. Although the same information is displayed, the spatial layout of that information differs in a number of ways. The purpose of this experiment is to evaluate the effectiveness of different layouts for displaying radio frequencies.

The approaches of chart publishers **Jeppesen** Sanderson Inc. and NOAA to the layout of radio frequencies differ from one another. Appendix A shows how the two publishers portray this information. **Jeppesen** Sanderson Inc. left justifies the facility name with the frequency to its right separated by one space. NOAA also left justifies the facility name, but places the frequency in one of two locations: left justified and beneath the facility name or

one space to the right of the name. Most of the time the frequency is beneath the name. In contrast to the close proximity of the radio frequencies to each other in the **Jeppesen** Sanderson Inc. and NOAA charts, the Canadian department of Energy, Mines, and Resources takes a very different approach. As shown in Appendix A, each radio frequency is enclosed in its own box and laid out horizontally along the top of the plan view. Inside each box, the facility name and frequency are centered, with the frequency located beneath the name.

All three chart types also differ in the use of formatting variables unrelated to spatial layout such as font size, font style, and the order in which the frequencies are laid out. In an effort to better understand the effects of layout on the presentation of radio frequencies, four unique layouts were designed for this experiment. Three of these designs are similar to the layouts used in the three chart types described previously. The four layouts are shown in Table 3. In layout 1, the frequency was located directly under the text, similar to the NOAA format for displaying the radio frequencies. In layout 2, the frequency was located directly to the right of the text as in the **Jeppesen** Sanderson charts. In layout 3, the facility names and frequencies were placed in two left justified columns separated by 0.15 inches. The name was located to the left of the frequency. In layout 4, each facility name and frequency pair was enclosed in a box across the top of the plan view as in the Canadian Energy, Mines, and Resources chart format.

**TABLE 3. FOUR LAYOUTS**

1	2	3	4	
Frequency under name	Frequency to right of name	Frequency to right of name & left justified	Frequency under name, boxed and centered	
<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<b>App</b> Con 121.7 <b>247.0</b>	Tower 122.3

This experiment evaluated the relative speed and accuracy with which pilots could find radio frequencies using the four layouts. A comparison of the four layouts addressed a number of questions.

First is it better to display the frequency to the right of the name or below the name? Given that it is normal to read prose from left to right and that this is a highly practiced habit in most readers, it is hypothesized that frequencies located to the right of the name will be read faster than frequencies placed underneath the name. A comparison between layouts 1 and 2 will address this question.

Second, is reading speed affected by the spatial separation of facility names and frequencies into two separate groups, or is it better to maintain close proximity so that the two items of information are perceived as belonging in the same column? A review of the literature by Wright (1977), indicates that readers find information faster when multiple items are separated than when they are viewed as belonging to the same column. A second hypothesis to be tested in this study, proposes that it is easier to find radio frequencies in tabular

columns in which the names are spatially separated from the frequencies. This hypothesis will be evaluated by comparing the two column format (layout **3**) to the one column formats (layouts 1 and **2**).

Finally, how does the Canadian approach, in which each text pair (facility name and frequency) is separated by boxes, compare to the approaches taken by publishers of United States **IAPs**. In addition to boxing the frequencies, the Canadian charts contain more space between text frequencies than the publisher's charts. One possible advantage of this type of layout compared to the NOAA layout is that it may mitigate the proximity effects of nearby text. The NOAA charts and to a lesser degree **Jeppesen** Sanderson charts place all the facility names and frequencies in close proximity to each other. The close proximity of the frequencies increases the likelihood that the frequency a pilot is not looking for may distract the reader during the search process and increase the chances of making an erroneous identification. **Noyes (1980)** reports that **distractors** in the proximity of a word being fixated increases the search time. The Canadian charts with their greater separation between items may be read more quickly as there are fewer **distractors** in close proximity. A comparison between the boxed format (layout **4**) and the one column formats (layouts 1 and **2**) will address this question. It was hypothesized that layout **4**, with a larger amount of space separating the radio frequencies would exhibit faster response times than layouts 1 and **2**.

## 3.2 METHODOLOGY FOR EVALUATING LAYOUT

### 3.2.1 Design

A mixed two factor design with one between-subjects factor (pilot rating) and one **within**-subjects factor (layout) was used (shown in Table 4). There were two levels of pilot rating, Instrument Flight Rules (**IFR**) and Visual Flight Rules (**VFR**), and four types of layout: frequency under name, frequency to the right of the name, two columns, and boxed. Table 3 illustrates the four layouts. Layout 1 displayed the frequency below the facility name. Layout 2 displayed the frequency one space to the right of the name. Layout 3 displayed the facility name and frequency in two left justified columns separated by **0.15** inch. Layout 4 displayed each facility name and frequency in its own box; the boxes were placed across the top of the chart plan view.

**TABLE 4. LAYOUT EXPERIMENTAL DESIGN**

	Type of Spacing			
	Frequency under text	Frequency to right of text	Frequency to right, left justified	Frequency under text, boxed, centered
Pilot Rating	<b>IFR</b>	<b>IFR</b>	<b>IFR</b>	<b>IFR</b>
	<b>VFR</b>	<b>VFR</b>	<b>VFR</b>	<b>VFR</b>

The experiment was conducted in four blocks. A block consisted of **20** trials using stimuli of the same layout type throughout that block. A **latin** square was used to balance the presentation of the four blocks. Within a block, trials were randomized. The subject was asked to report one of two civil frequencies: Approach Control or Tower. Searching for the frequency was counterbalanced by asking half the subjects to search for the approach control frequency for the first two blocks and the tower frequency for the last two blocks, and asking the other half to do the opposite.

### 3.2.2 Stimulus Construction

The experimental stimuli were modeled after the NOAA instrument approach plates. The experimental and sample charts were created from scratch on an Apple Macintosh computer using the graphics program Canvas by **Deneba** Systems. The charts were photographed and mounted in pin registered slide mounts.

Twenty one charts were created from six original chart templates. The stimuli were created by changing the airport names and radio frequencies and rearranging obstructions in the plan view. Fictitious frequencies in the VHF bandwidth were randomly assigned to the charts.

On each of the twenty-one chart templates the layout of the radio frequencies was modified four times creating a total of **84** stimuli. Only the format of the radio frequencies was modified; all other information on the chart remained constant. An example of the each layout type is shown in Appendix **E**.

### **3.2.3 Procedures**

The subject was told that he would see a series of instrument approach plates, and instructed to search for the target frequency as quickly and accurately as possible. The experimenter briefly described each layout type and presented examples of the four layouts.

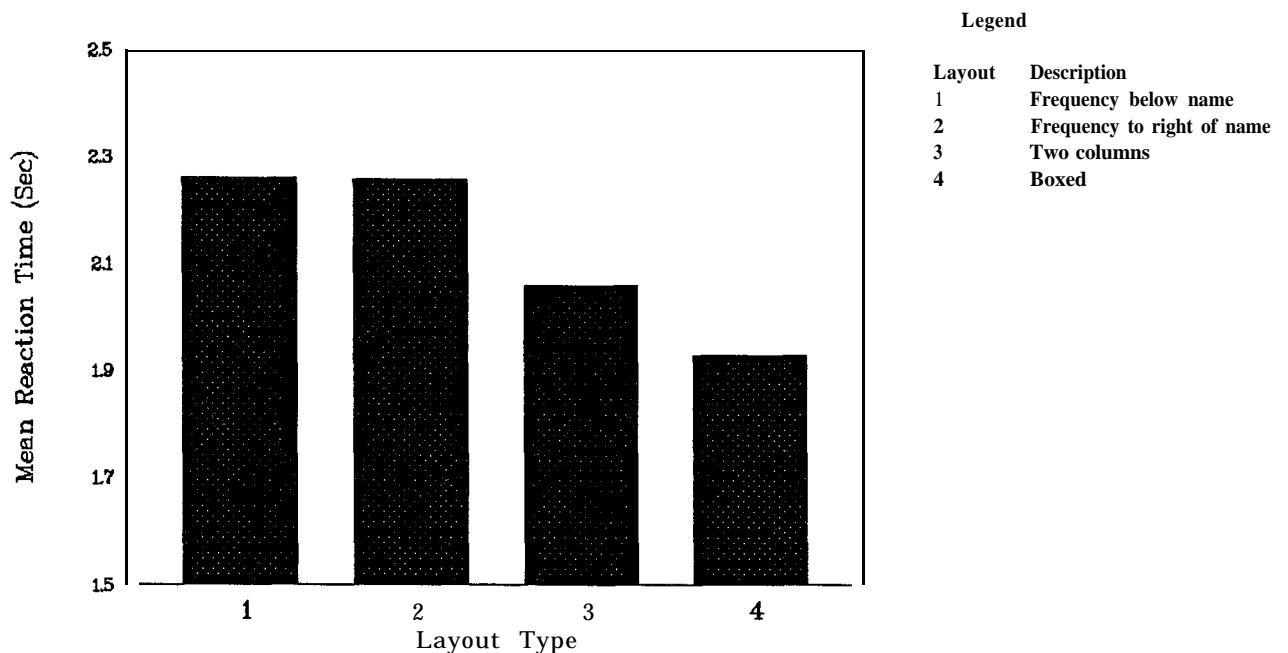
The subject completed 4 blocks of **20** trials. At the start of each new block, the subject viewed a sample chart for five seconds to become familiar with the chart format to follow. Between each block there was a brief rest period (**2-4** minute).

### 3.3 RESULTS AND DISCUSSION

#### 3.3.1 Pilot Rating

An analysis of variance (**ANOVA**) was performed to determine whether there were differences in response time as a function of flight experience and to learn whether experience differentially affected performance. The **ANOVA** was not statistically significant,  $F(1,18) = 0.05$ ,  $p > .82$ , indicating that experience did not reliably affect how the two groups performed. The remaining analyses were performed on data collapsed across pilot rating.

#### 3.3.2 Layout Effects



**FIGURE 4. EFFECT OF LAYOUT ON MEAN RESPONSE TIME**

An Analysis of Variance (**ANOVA**) revealed a significant effect of layout for mean response time  $F(3,57) = 10.89$ ,  $p < .0001$ . Figure 4 illustrates the relationship between the type of layout and mean response time. Mean response time was almost identical for the layouts with the frequency below the name (layout 1) and to the right of the name (layout 2), corresponding to the NOAA and Jeppesen Sanderson Inc. formats, respectively. The two layouts differed by **0.01** milliseconds (**msec.**). These two layouts exhibited the longest mean response times. The two column layout (layout 3) and the boxed layout (layout 4) exhibited faster mean response times. Although subjects performed faster in the boxed layout than in the two column layout, the difference was not statistically significant. However, a **Student-Newman-Keuls** test of pair-wise comparisons indicated that both the two column and boxed



layouts were significantly different from the other two layouts:  $CR_{\alpha} (3,57) = .1846, p < .05$ . This relationship accounts for the statistically significant effects of layout type found in the ANOVA.

The results of an analysis of errors made identifying the frequency found an error rate of **5.31% (85 out of 1600)**. A Friedman two-way analysis of variance found no statistically significant relationship between error rate and layout type.

Subject preferences for the four layouts **were** consistent with the mean response time measures. Subjects were asked to rank their preferences from 1 to 4, where 1 was the most preferred and 4 was the least preferred. Table 5 shows the rank totals, where each score represents the number of ranks assigned that score multiplied by that score (i.e. 1-4). The lower the rank **total**, the more that layout was preferred. The boxed and two column layouts were both preferred over the other two layouts. A Friedman two-way analysis of variance found these difference to be statistically significant  $X^2_r (3) = 8.16, p < .05$ .

**TABLE 5. SUBJECT PREFERENCE FOR 4 LAYOUTS**

Layout Type	Rank Total
Frequency below name	<b>58</b>
Frequency to right of name	<b>61</b>
Two columns	<b>42</b>
<b>Boxed</b>	<b>38</b>

The data from this experiment contradicted the hypothesis that placing the frequency to the right of the facility name would improve performance compared to placing the frequency below the name. Performance in these two layouts (**1** and **2**) were virtually identical. The expectation that performance would be faster when the frequency is to the right of the name because of the well practiced habit of reading from left to right may be mitigated by the small amount of text to be read and/or the close proximity between text elements.

The comparison between the two column layout (**3**) and layouts with the text close together in one column (**1** and **2**), supports the notion that spatially separating names and frequencies into separate columns improves performance. Performance was faster in the two column layout than in the one column layout. Similarly, the effects of spatial separation were also observed in the comparison between the boxed layout (**4**) and the one column layouts. The best performance was observed in the boxed condition. In the case of the two column format, the horizontal spacing between the name and frequency may aid the reader because it conforms to well established reading habits. The reader would search the left-column for the appropriate name then read the frequency from the corresponding right-hand column, moving his eyes from left to right. Similarly, in the boxed condition, the reader would move his eyes from left to right until the appropriate name was found and then read the corresponding frequency underneath. The space between the two columns may also act like the black lines

surrounding the text pairs in the boxed condition; it acts like a frame to separate words. Both the space and the lines guide the reading process.

Additionally, the greater space between the two columns and between the text pairs in the boxed condition reduces the likelihood that surrounding text will act as a potential distractor. This finding is consistent with **Noyes' (1980)** recommendation that words in a map display be kept clear of surrounding materials to aid processing speed. In the experiments conducted by **Noyes (1980)** the **distractors** were within 1 space of the target word. For both of the one column layouts, the facility name and frequency were separated by a single space. To facilitate reading the radio frequencies, the layouts could benefit from more than one space between items. However as the effectiveness of both the two column and the boxed layouts demonstrate, there are multiple methods for achieving this goal.

### 3.4 CONCLUSIONS

This experiment evaluated the effectiveness of four layouts for displaying radio frequencies. The purpose was to evaluate the use of spatial layout on the readability of instrument approach plates. The data indicate that spatial layout affects the speed with which **IAPs** can be read.

The two layouts analogous to the formats used by NOAA and **Jeppesen** Sanderson Inc. resulted in similar performance. Neither layout was more effective than the other. These layouts presented facility names and frequencies in one column with the frequency either to the right or beneath the associated name. The data from this experiment should not be used to suggest that the presentation of radio frequencies on charts published by NOAA and **Jeppesen** Sanderson Inc. are equally effective. This experiment did not address that question. The presentation of radio frequencies by the two publishers differ by more than just spatial layout (e.g., fonts used, **bolding**, location of frequencies on the chart).

Performance in a two column layout and a boxed layout analogous to the format of charts published by the Canadian Department of Energy, Mines, and Resources was superior to both of the one column formats. Both of these two layouts used space to actively organize the placement of text. The two column layout uses white space to separate the names and frequencies into two columns and the boxed layout uses white space to separate the name and frequency text pairs horizontally along the top of the plan view. Further, more space was used than in the one column layouts. These data suggest that current **IAPs** may benefit from designs like those found in the Canadian charts that use more space to separate facility names and frequencies.

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## APPENDIX A: INSTRUMENT APPROACH PLATES OF THREE PUBLISHERS

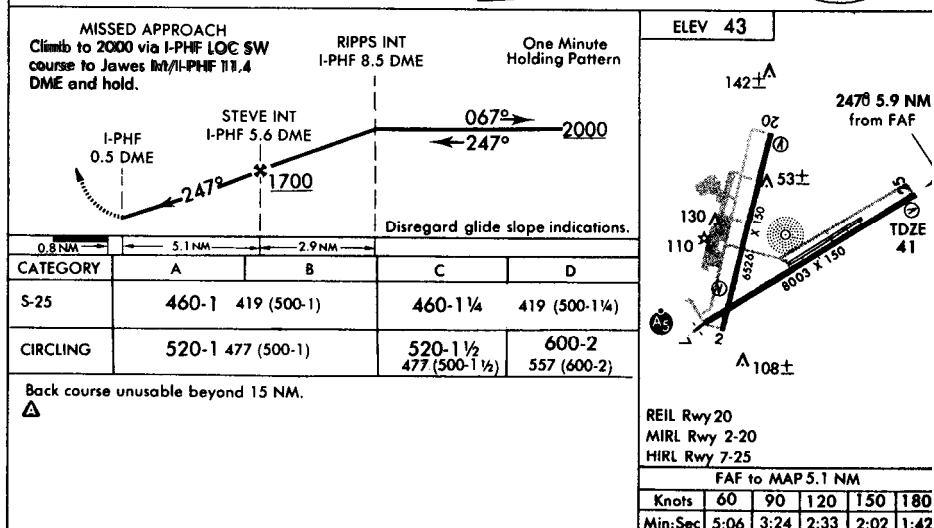
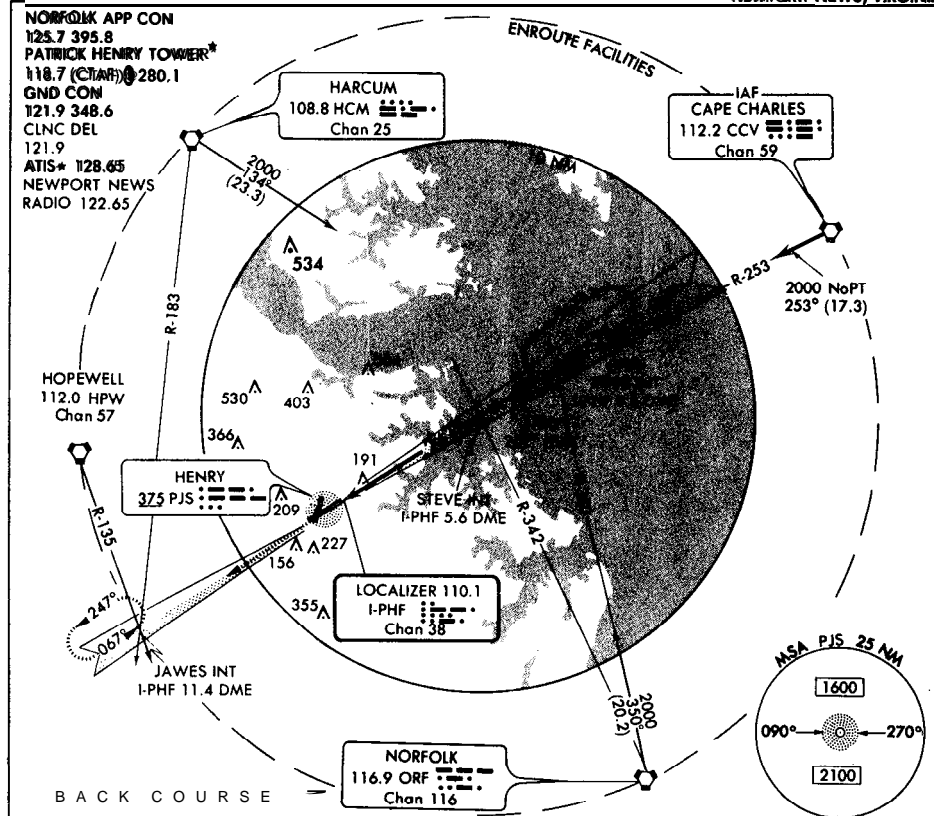
	Page
National Oceanic and Atmospheric Administration . . . . .	27
<b>Jeppesen</b> Sanderson Inc. . . . .	28
Canadian Department of Energy, Mines, and Resources . . . . .	29

# National Oceanic and Atmospheric Administration

Amdt 13 89012

## LOC BC RWY 25

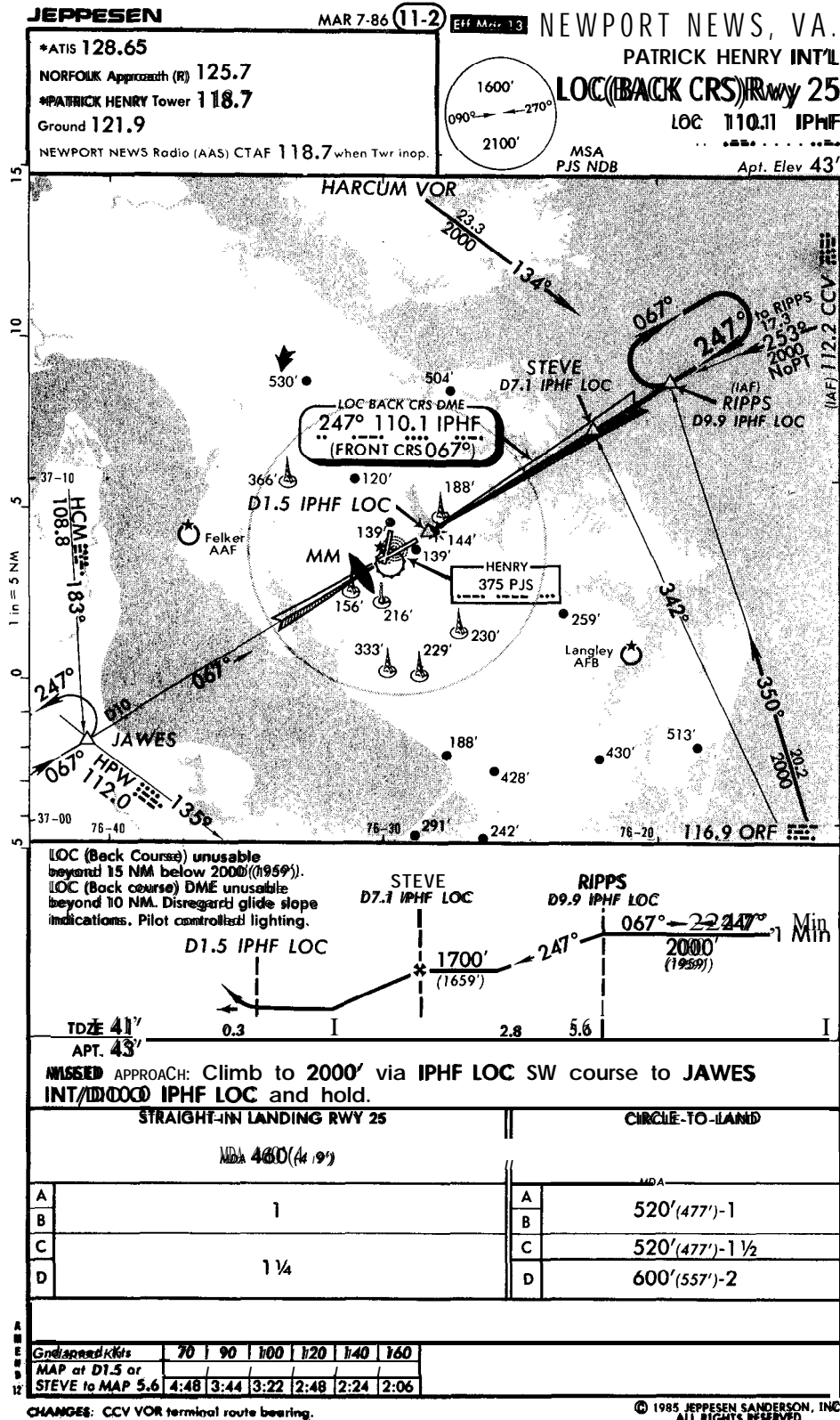
NEWPORT NEWS/PATRICK HENRY INTL (PHF)  
AL-957 (FAA)  
NEWPORT NEWS, VIRGINIA



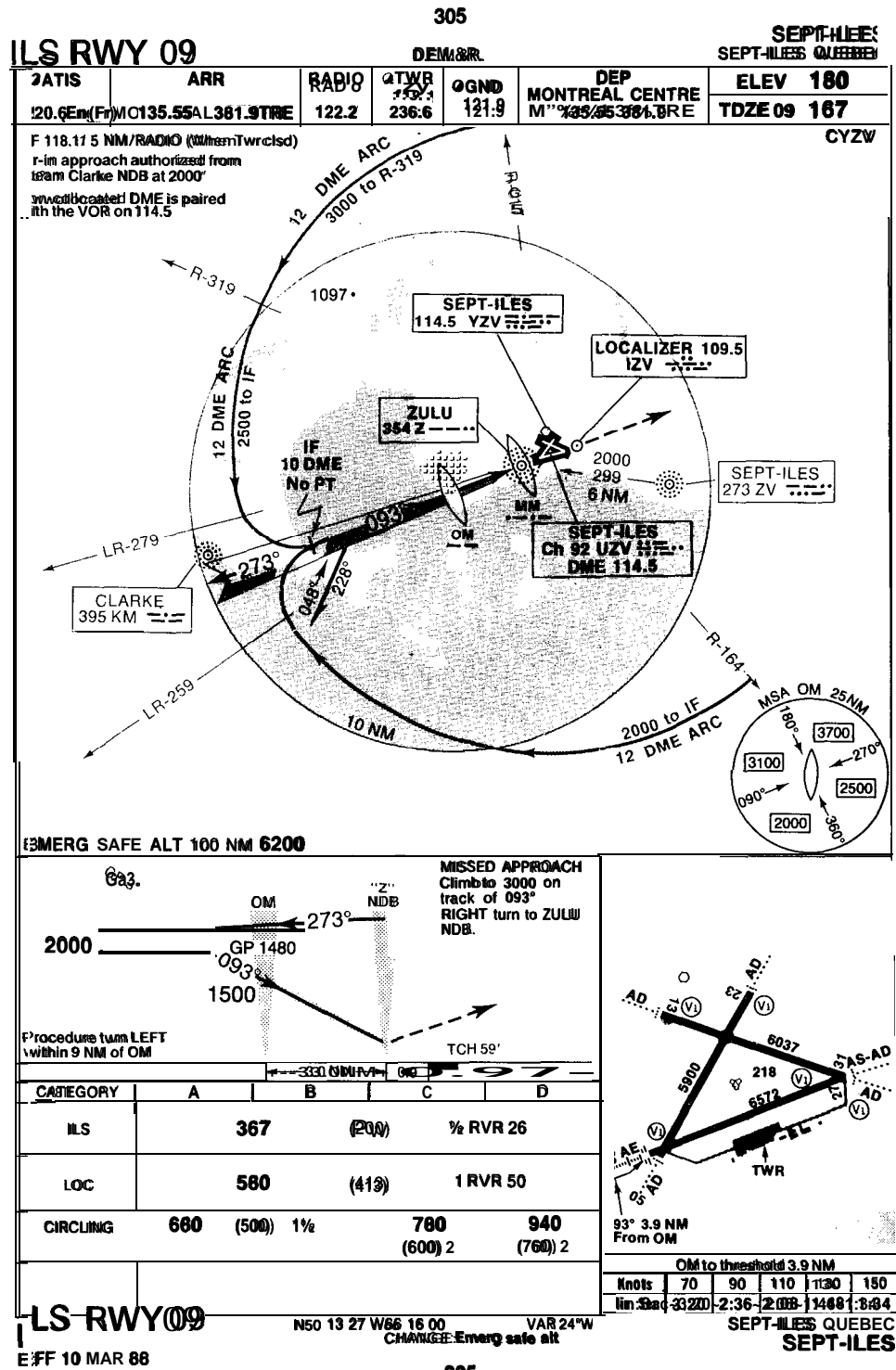
## LOC BC RWY 25

37°08'N-76°30'W  
NEWPORT NEWS, VIRGINIA  
NEWPORT NEWS/PATRICK HENRY INTL (PHF)

# Jeppesen Sanderson



Canadian Department of Energy, Mines and Resources





**APPENDIX B: SUBJECT INSTRUCTIONS**

	Page
General Instructions . . . . .	<b>31</b>
Instructions for the Layout Experiment . . . . .	<b>32</b>
Instructions for the Highlighting Experiment ; . . . . .	<b>33</b>

## General Instructions

We're going to run three experiments today. They are all similar. Your task is to use different kinds of fictitious approach plates to locate and identify information necessary to make safe instrument landings.

**IFR PILOTS** - If you're familiar with approach plates, you may find that we have made mistakes in some of the information shown on the charts. However, since our experiment does not depend on their accuracy please bear with the mistakes and try to concentrate on the primary task.

**VFR PILOTS** - If you don't have any experience with the charts don't worry. There is a lot of information on the charts and they can be very confusing at first, but we will tell you all you need to know to find the information that we are interested in.

First, I will tell you about the procedures that are common to all the experiments. At the beginning of each of the experiments, I'll give you specific instructions. Please ask questions at any time.

Each experiment consists of several sets of blocks. A block consists of a set of trials. One trial consists of locating and identifying a specific item of information on an approach plate. The plates will be shown on a screen directly in front of you. Please do not touch the screen during the experiments. The experiments differ in the number of trials per block and in the total number of blocks. You will not have to concentrate on the task for more than a few minutes at a time and there will be plenty of opportunities for breaks.

There are three steps within a trial. First, you will see a "fixation point" slide. This is a slide with a cross on it. Focus on the center of this cross until it goes away. An approach plate slide will immediately appear in its place. You will search for the information we tell you to look for. When you find it, press the button located on the desk in front of you and call out the number you see. You do not need to shout; just speak at a normal level. There is a camera used to pick up audio located on a side wall. Once you press the button, there will be a short pause before the next trial begins.

Please note that once you have pressed the button, you cannot bring back the approach plate, so be sure of your response. We would like you to do the task very accurately, but also quickly. Try to keep your error rate very low. If we see that you are making a lot of errors, we will ask you to be more careful.

Now you can practice this procedure. ***(Walk the subject to the other room where the experiment will take place.)*** Here are a set of 20 practice trials which we would like you to read off the name of the airport. We can run more practice trials if you still have questions about the procedure. Do you have any questions before we begin the first experiment?

## Instructions for the Layout Experiment

This experiment has 4 blocks with **20** trials per block. You will be looking for radio frequencies on the charts, specifically Tower and Approach Control. I will tell you which you will be searching for immediately before a block.

The frequencies will always be located on ~~the upper~~ portion of the plan view, but will be displayed in four unique ways. You will look for civil frequency which is the number located at the beginning of the left margin. You only have to report the frequency. You do not need to say the type or name of the frequency.

Remember, all the frequencies are fictitious. Don't be alarmed if you get an emergency frequency or any other frequency you know would not be a approach or tower frequency.

We've changed the layout of the charts. The following are examples of the four changes.

Show each chart type and describe:

Layout 1 : Frequency under the text.

Layout 2 : Frequency to the right of the text.

Layout 3 : Frequency to the right and left justified.

Layout 4 : Frequencies located in boxes across the top.

A block consists of **20** trials of each layout type. You will see 4 blocks of **20** trial each. Each block will be divided by a short break of 1 to 2 minutes. At the beginning of each block we show you an example of the type of chart you will be seeing for this block. This example will be shown for 5 seconds. The chart will be displayed automatically so you don't have to respond in any way to this example. After the example goes away you will see a fixation slide which signals the beginning of the trial, followed by the experimental plate. When you find the frequency you are to search for press the button and say the frequency aloud.

At this time I will be tell you whether to search for the approach control or the tower frequency. ***Tell the subject the type of frequency to search for. You*** will search for the Approach (Tower) first. Remember the frequencies are fictitious.

Do you have any questions?

## Instructions for the Highlighting Experiment

The information you will be looking for is the inbound approach heading. **Show subject an approach plate if unfamiliar with LPS.** It is located along the inbound approach. If this is the airport, follow the line back to find the heading. Don't mistake the holding pattern heading for the inbound heading. **Flip through at least ten charts to make sure the subject understands.**

North is approximately vertical. It is not always exact. It may be off in either direction, just as it is in the real world. We've changed the way the heading is displayed. We've highlighted it in various ways. **Show the subject each type of highlighting condition by pointing to the changed approach heading in the sample chart booklet.**

This experiment consists of **16** blocks of 5 trials per block. A block consist of 5 charts of each highlighting type. Just as in the last experiment, we will show you an example of the type of chart you will be seeing in this block, at the beginning of each block. The example will be shown for 5 seconds and will be displayed automatically. You don't have to respond in any way to this example chart. After the example goes away you will see a fixation slide which signals the beginning of the trial.

Remember there are **16** blocks in this experiment. The **16** blocks will be divided into 4 sets of 4 blocks. We will break for a few minutes between each set of 4 blocks and I will come in to see how you are.

Within a set of 4 blocks I won't come in. However, there will be a **15** second break between the blocks; enough time to relax briefly, take your chin off the chin rest, and look around. Then the example slide for the next block will appear on the screen.

You will always be looking for the Approach heading.

## APPENDIX C: QUESTIONNAIRES

	Page
General Experience . . . . .	35
Effect of Layout on Frequency Readability . . . . .	37
Effect of Highlighting on Approach Plate Readability . . . . .	39

## BRIEFING/DEBRIEFING QUESTIONNAIRE

Date: \_\_\_\_\_

### SECTION 1

Subj# \_\_\_\_\_

#### General Experience

1. Approximately how many flight hours do you have? \_\_\_\_\_ hours

2. Indicate the type of civil aviation experience you have?

Part **121**      Part **135**      General Aviation      Corporate

3. Do you have any military flight experience?      Yes      No

If yes, approximately how many flight hours      \_\_\_\_\_ hours

4. Are you licensed to fly under **IFR** conditions?      Yes      No

5. Rate your experience with instrument approach plates

Never use   Rarely      Sometimes   Frequently   Always use

1                  2                  3                  4                  5

If **you** have **no experience** using approach plates, **Stop here.**

6. Rate the frequency with which you use the following instrument approach plates:

Never      Rarely      Sometimes   Frequently   Always

**Jeppesen**      1                  2                  3                  4                  5

NOAA/DOD   1                  2                  3                  4                  5

Other                  1                  2                  3                  4                  5

7. Rank your preference for the following instrument approach plates, where 1 is the most preferred and 3 is the least preferred. Enter N/A in "Other" if you have experience only with **Jeppesen** and NOAA charts:

**Jeppesen**

NOAA/DOD     

Other                  Specify: \_\_\_\_\_

8. Do you mark up your instrument approach plates? Yes No

If yes, briefly describe the information you mark up and why?

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## SECTION 2

### Experiment A: Effect of Layout on Frequency Readability

#### Four Layouts

A	B	C	D	
Frequency under name	Frequency to right of name	Frequency to right of name & left justified	Frequency under name, boxed and centered	
<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<b>App</b> Con <b>121.7 247.0</b> Tower <b>122.3</b>	<div><div>App Con</div><div>121.7</div><div>247.0</div></div>	<div><div>Tower</div><div>122.3</div></div>

- Please rank the layouts from 1 to 4 according to how easily you were able to find the communication frequency requested. 1 is the layout you found frequencies the easiest and 4 is the layout that was the hardest to find frequencies.

Frequency under name  
 Frequency to right of name  
 Frequency to right of name, left justified  
 Frequency under name, boxed and centered

- Please rank your preference from 1 to 4 for the layouts you saw, where 1 is the layout you liked most and 4 is the layout you liked least.

Frequency under name  
 Frequency to right of name  
 Frequency to right of name, left justified  
 Frequency under name, boxed and centered

- Are you aware of problems that you or others have in using communication frequencies on the plates?    ☐ Yes    ☐ No

If yes, briefly describe these problems:

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4. Do you think that communication frequencies need to be more readable?  
Yes      No

If yes, what design changes would you like to see to make the communication frequencies more readable?

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## SECTION 3

### Experiment B: Effect of Highlighting on Approach Plate Readability

#### Four Types of Highlighting

A	B	C	D
None	Bold	Box	Reverse Video
121°	121°	121°	121°

1. Please rank the types of highlighting from 1 to 4 according to how easily you were able to find the inbound heading, where 1 is the easiest and 4 is the hardest.

None  
 Bold  
 Box  
 Reverse video

2. Please rank the highlighting methods you saw, from most preferable (1) to least preferable (4).

None  
 Bold  
 Box  
 Reverse video

#### Two Font Sizes

A	B
9	12
121°	121°

3. How did letter size affect the ease with which you found the inbound heading?

I found **larger** size headings more easily  
 I found **smaller** size headings more easily  
     I found both letter sizes with **equal ease**  
 don't know

### Text Orientation

A	B
No Rotation	Rotated Text
121°	121°

4. Were you able to find the heading more easily when it was:

at the same orientation as the heading  
on the horizontal axis  
makes no difference which way heading is positioned  
don't know

5. In your opinion, is it better to present the inbound heading

at the same orientation as the heading  
on the horizontal axis  
makes no difference which way heading is positioned

comments:

---

---

---

---

6. Are you aware of problems that you or others have in using inbound heading on the approach plate? \_\_\_\_ Yes      No

comments:

---

---

---

---

7. Should the heading be easier to read?      Yes      No

If yes, what design changes would you like to see to make the inbound heading more readable?

---

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## **APPENDIX D: HIGHLIGHTING IAP TEMPLATES**

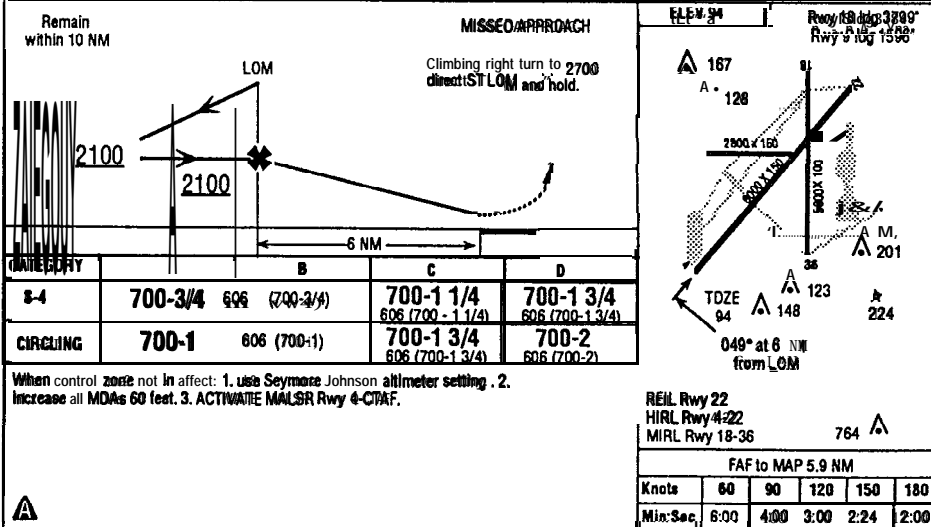
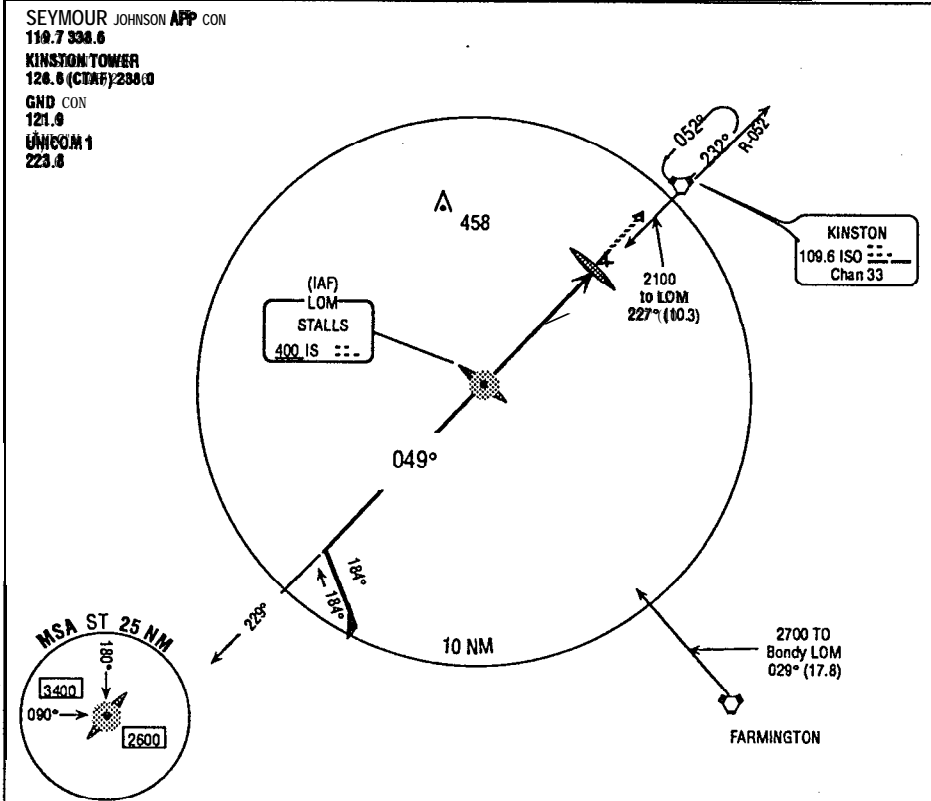


Font Size 9  
 Highlighting None  
 Text Unrotated

Amdt 8

**NDB RWY 4**

**KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)**  
 KINSTON, NORTH CAROLINA



**NDB RWY 4**

**KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)**  
 KINSTON, NORTH CAROLINA

Font Size 9  
 Highlighting Bold  
 Text Rotated

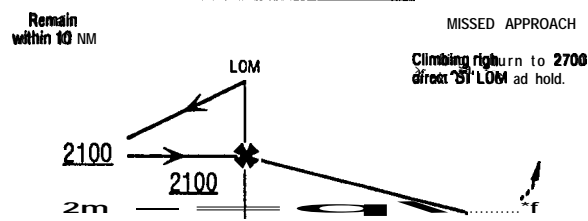
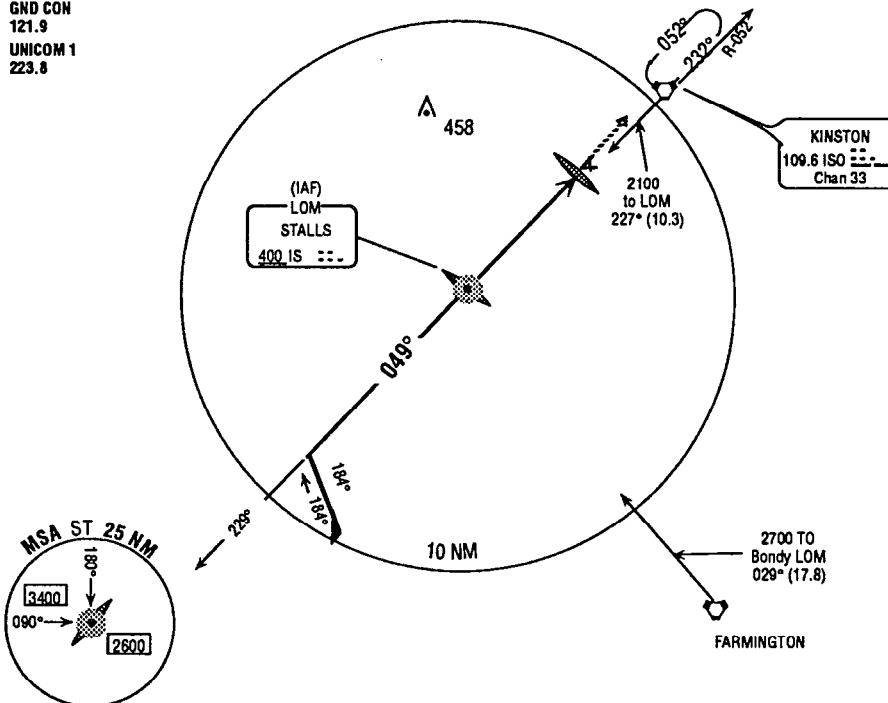
234

Amdt 8

# **NDB RWY 4**

KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)  
 KINSTON, NORM CAROLINA

SEYMOUR JOHNSON APP CON  
 119.7 334.6  
 KINSTON TOWER  
 128.6 (CTAF) 236.0  
 GND CON  
 121.9  
 UNICOM 1  
 223.8



CATEGORY	A	B	C	D
3-4	700-3/4	606 (700-3/4)	700-1 1/4 606 (700-1 1/4)	700-1 3/4 606 (700-1 3/4)
CIRCLING	700-1	606 (700-1)	700-1 3/4 606 (700-1 3/4)	700-2 606 (700-2)

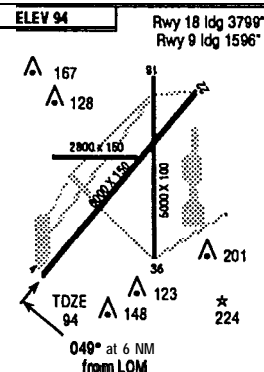
When control zone not in effect: 1. use Seymour Johnson altimeter setting. 2. Increase all MOAs 60 feet. 3. ACTIVATE MALSR RWY 4-CTAF.



# **NDB RWY 4**

35°20'N - 77°30'W

KINSTON, NORTH CAROLINA  
 KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)

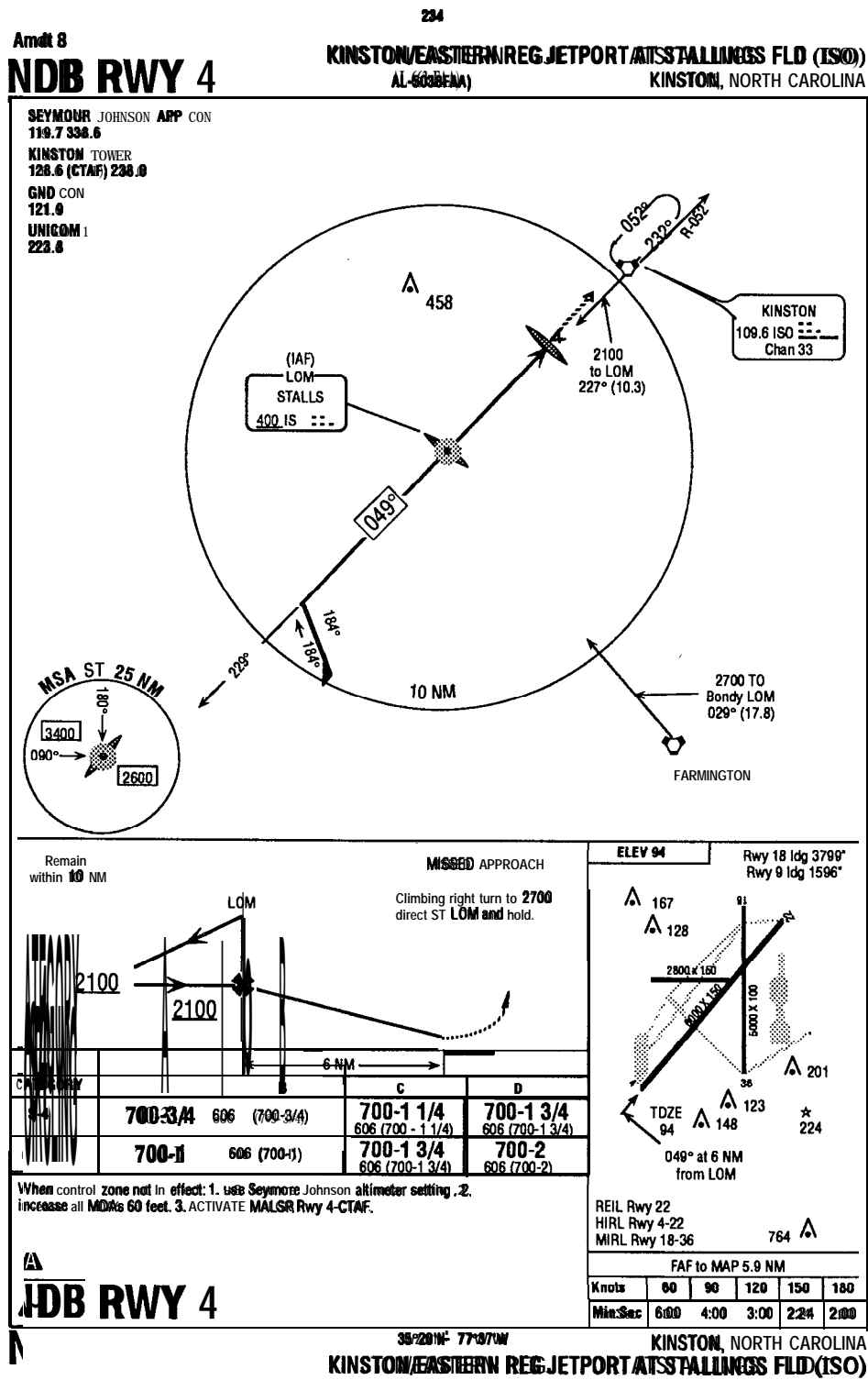


REIL RWY 22	
HIRL RWY 4-22	
MIRL RWY 18-36	
FAF to MAP 5.9 NM	
Knob	60 90 128 150 180
Min:Sec	6:00 4:00 3:00 2:24 2:00





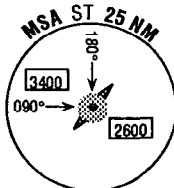
Font Size 9  
Highlighting Boxed  
Text Rotated



1

# NDB RWY 4

AL-50385A)



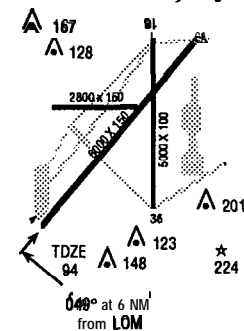
Climbing **right** turn  
direct ST **LOM** and

**2100**

**2100**

**6 NM**

When control zone not in effect: 1. use Seymore Johnson altimeter selling. 2. increase all MOAs 60 feet. 3. ACTIVATE MALSR Rwy 4-CTAF.



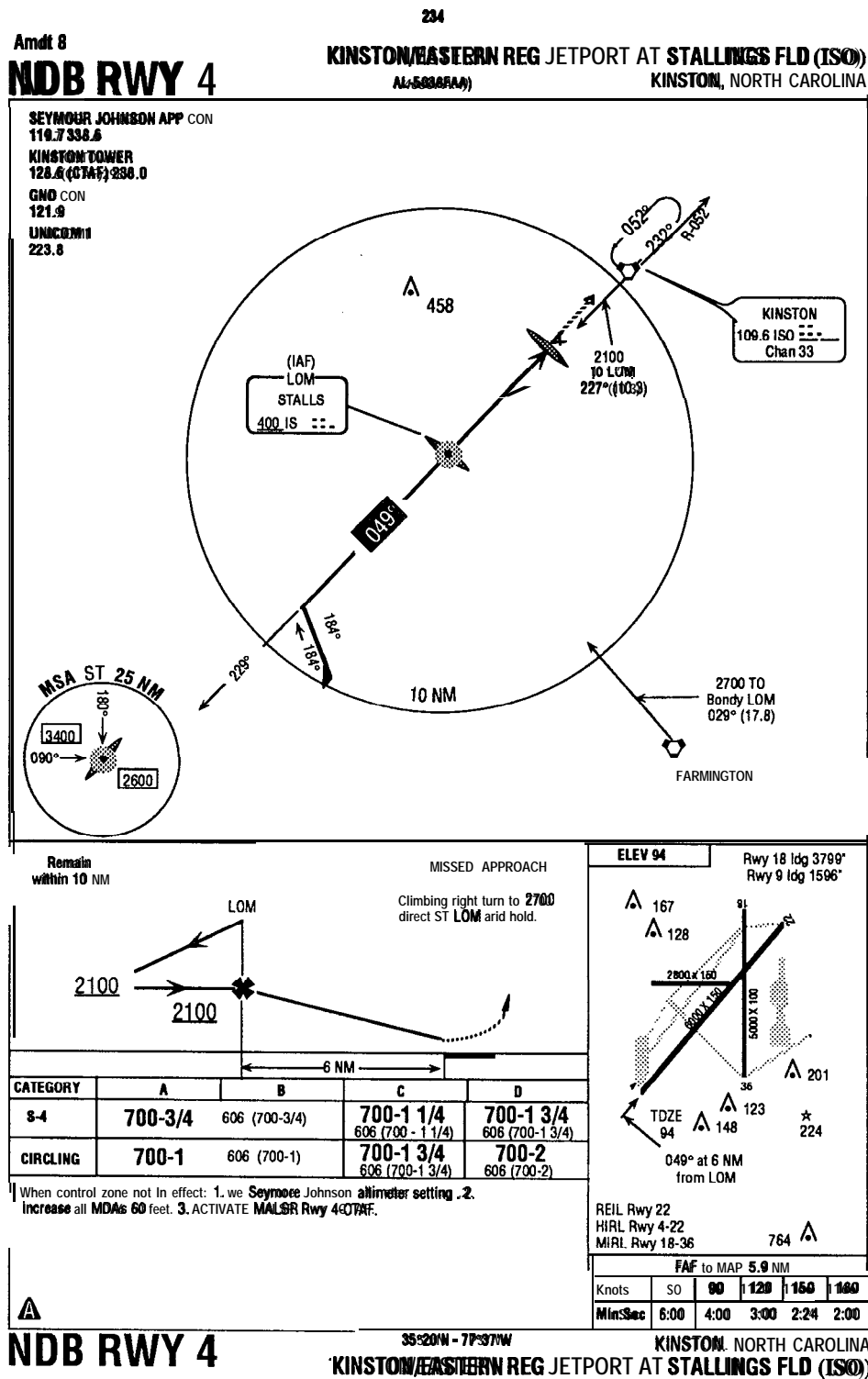
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---------	------	------	------	------	------

**NDB RWY 4**

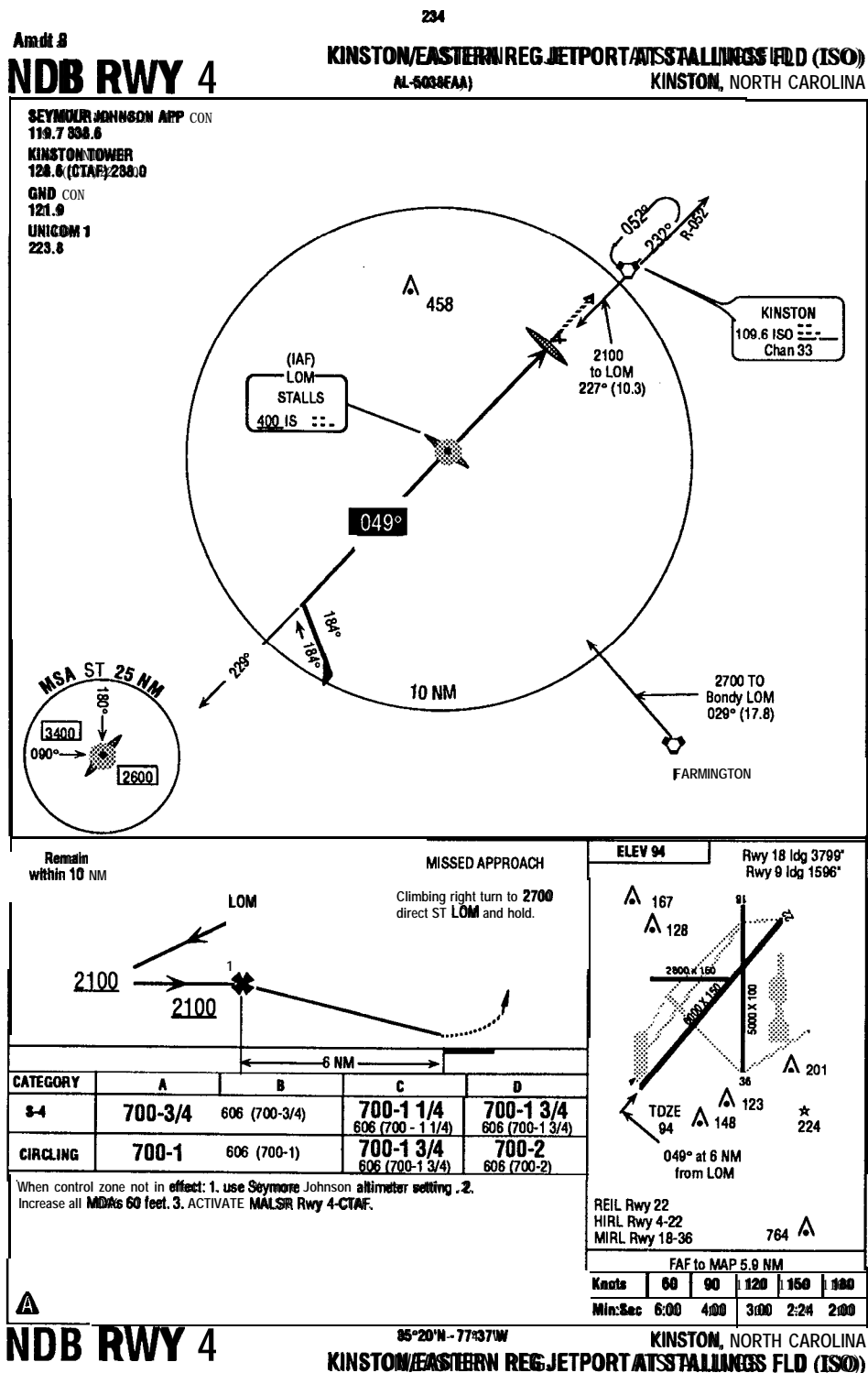
**35°20'N - 77°37'W**      **KINSTON, NORTH CAROLINA**  
**KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)**

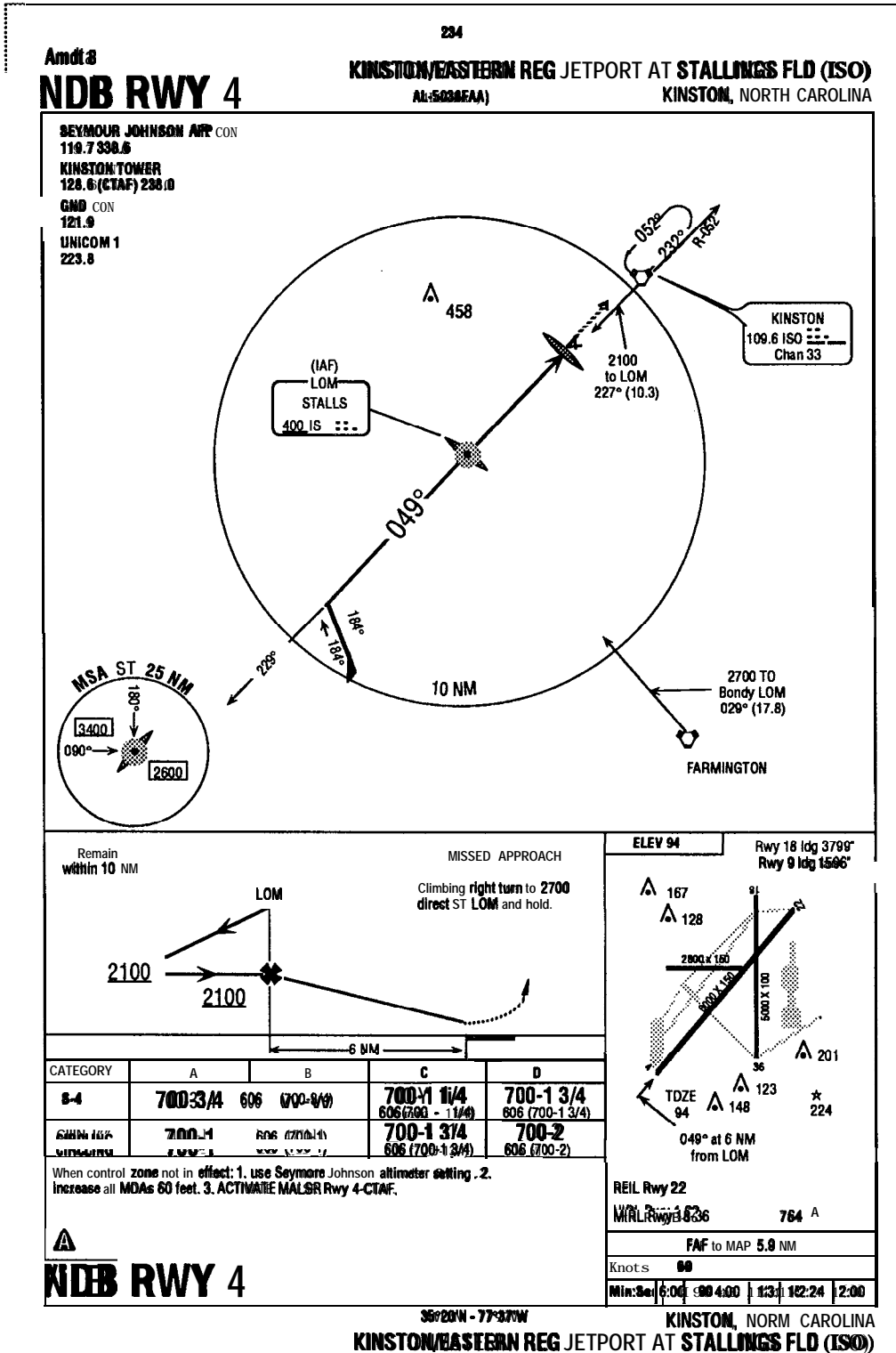
Font Size  
Highlighting  
Text

## 9 Reverse Video Rotated



Font Size 9  
 Highlighting Reverse Video  
 Text Unrotated





Font Size 12  
 Highlighting None  
 Text Unrotated

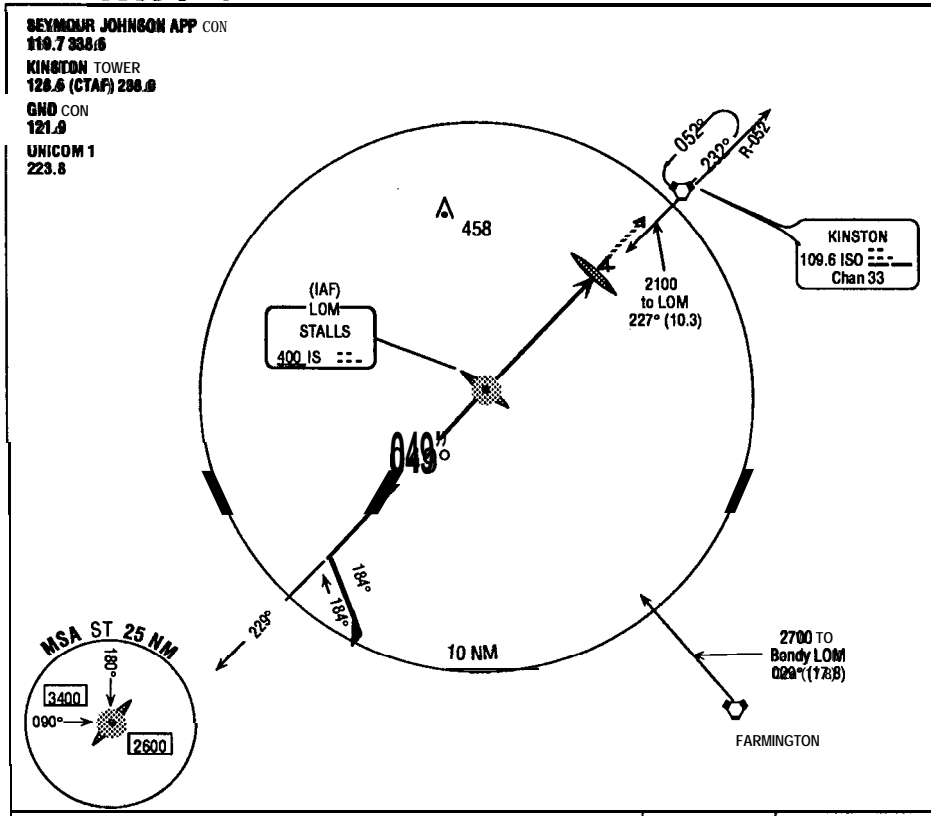
284

Amdt 8

# **NDB RWY 4**

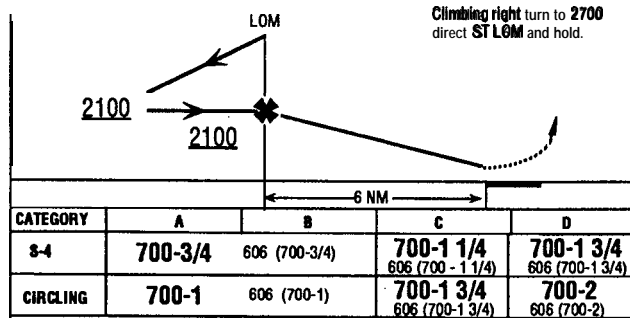
**KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)**  
 KINSTON, NORTH CAROLINA

SEYMOUR JOHNSON APP CON  
 119.7 338.6  
 KINSTON TOWER  
 128.6 (CTAF) 286.8  
 GND CON  
 121.6  
 UNICOM 1  
 223.8



Remain  
within 10 NM

MISSED APPROACH



CATEGORY	A	B	C	D
8-4	700-3/4	606 (700-3/4)	700-1 1/4 606 (700-1 1/4)	700-1 3/4 606 (700-1 3/4)
CIRCLING	700-1	606 (700-1)	700-1 3/4 606 (700-1 3/4)	700-2 606 (700-2)

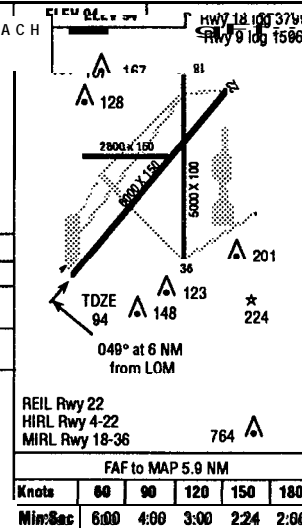
When control zone not in effect: 1. use Seymour Johnson altimeter setting. 2. Increase all MDAs 60 feet. 3. ACTIVATE MALSR Rwy 4-CTAF.



# **NDB RWY 4**

36°20'N - 77°37'W

**KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)**  
 KINSTON, NORTH CAROLINA



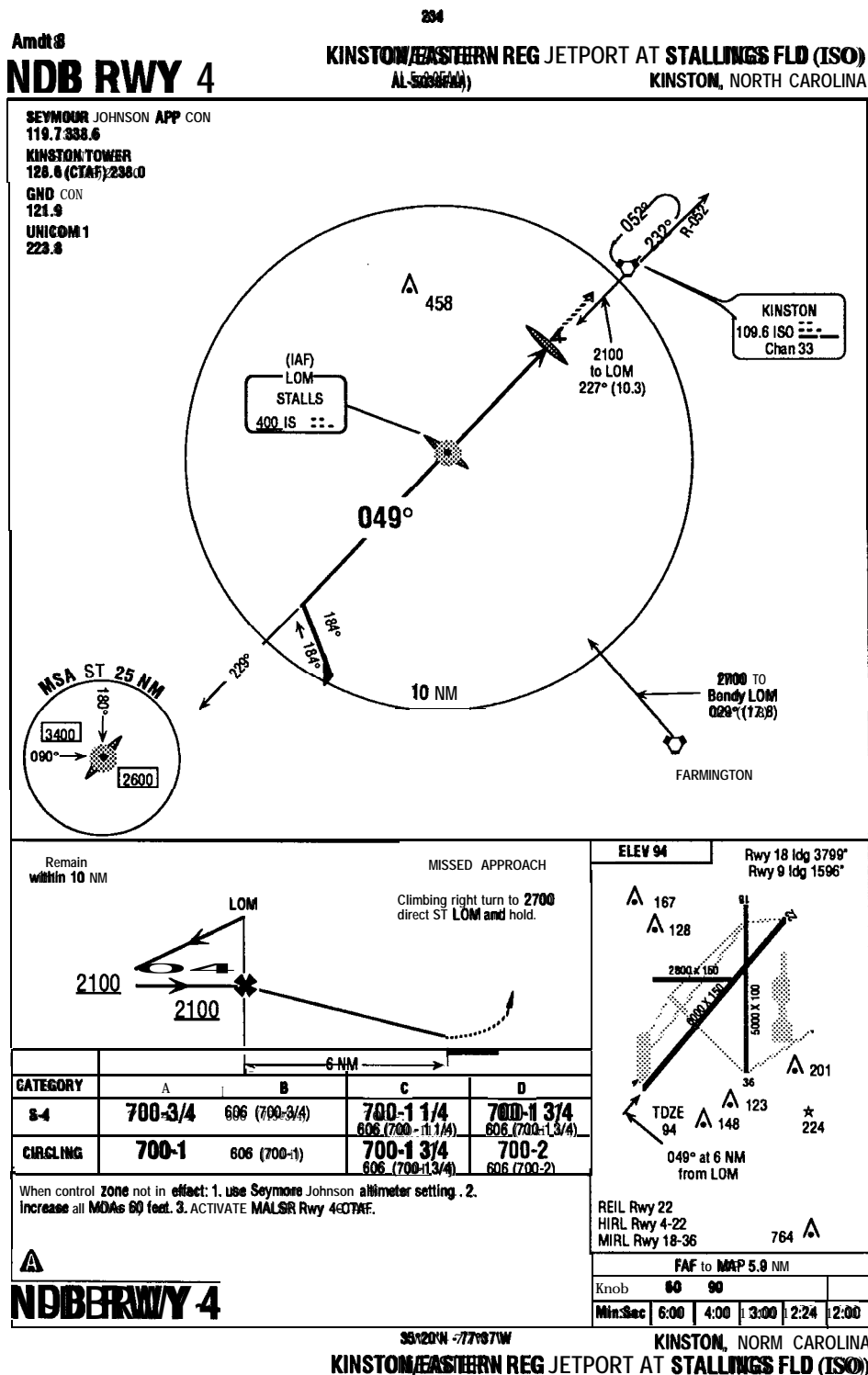
REIL Rwy 22  
 HIRL Rwy 4-22  
 MIRL Rwy 18-36

FAF to MAP 5.9 NM					
Knots	80	90	120	150	180
Min:Sec	6:00	4:00	3:00	2:24	2:00





Font Size 12  
 Highlighting Bold  
 Text Unrotated



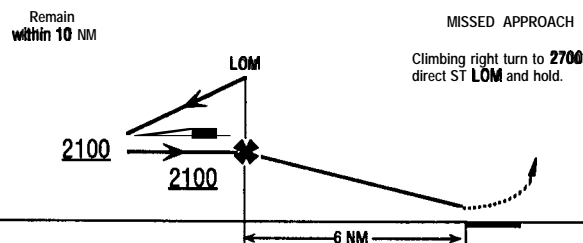
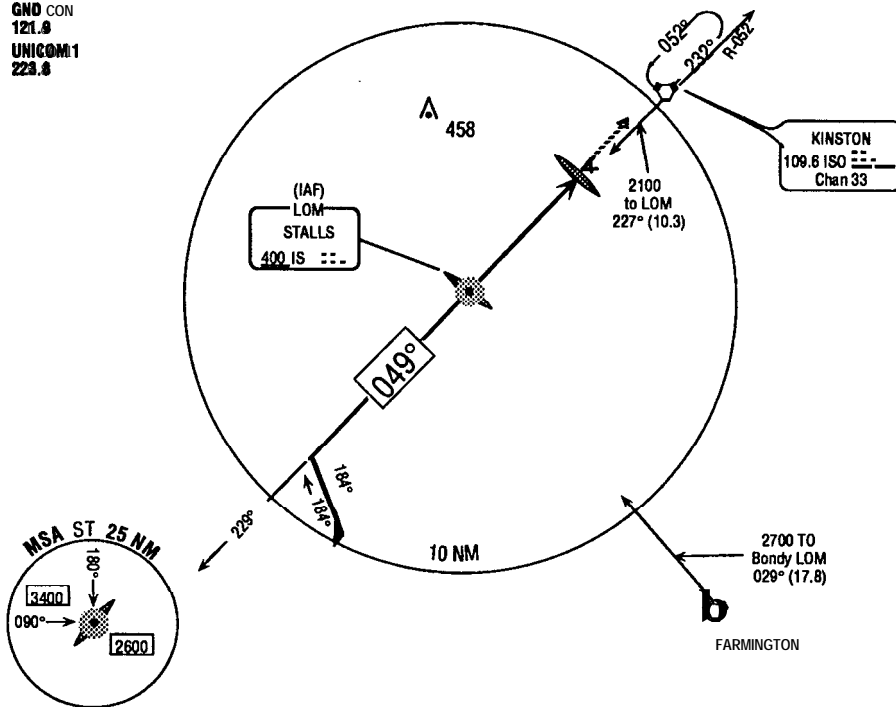
Font Size 12  
Highlighting Boxed  
Text Rotated

Amdt 3

# NDB RWY 4

KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)  
KINSTON, NORTH CAROLINA

SEYMOUR JOHNSON APP CON  
119.7.338.6  
KINSTON TOWER  
128.6 (CTAF) 238.0  
GND CON  
121.8  
UNICOM 1  
223.8



CATEGORY	A	B	C	D
3-4	700-3/4	606 (700-3/4)	700-1 1/4 606 (700-1 1/4)	700-1 3/4 606 (700-1 3/4)
CIRCLING	700-1	606 (700-1)	700-1 3/4 606 (700-1 3/4)	700-2 606 (700-2)

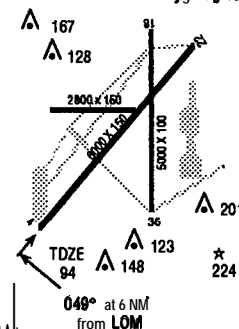
When control zone not in effect: 1. use Seymour Johnson altimeter setting. 2. increase all MDA's 50 feet. 3. ACTIVATE MALSR Rwy 4-CTAF.



# NDB RWY 4

KINSTON/EASTERN REG JETPORT AT STALLINGS FLD (ISO)  
KINSTON, NORTH CAROLINA

ELEV 94  
Rwy 18 ldg 3790°  
Rwy 9 ldg 1596



REL Rwy 22  
REL Rwy 4-22  
REL Rwy 18-36

FAF to MAP 5.0 NM				
	60	90	120	150
Min:Sec	8:00	4:00	3:00	2:24

**Font Size 12**  
**Highlighting Boxed**  
**Text Unrotated**

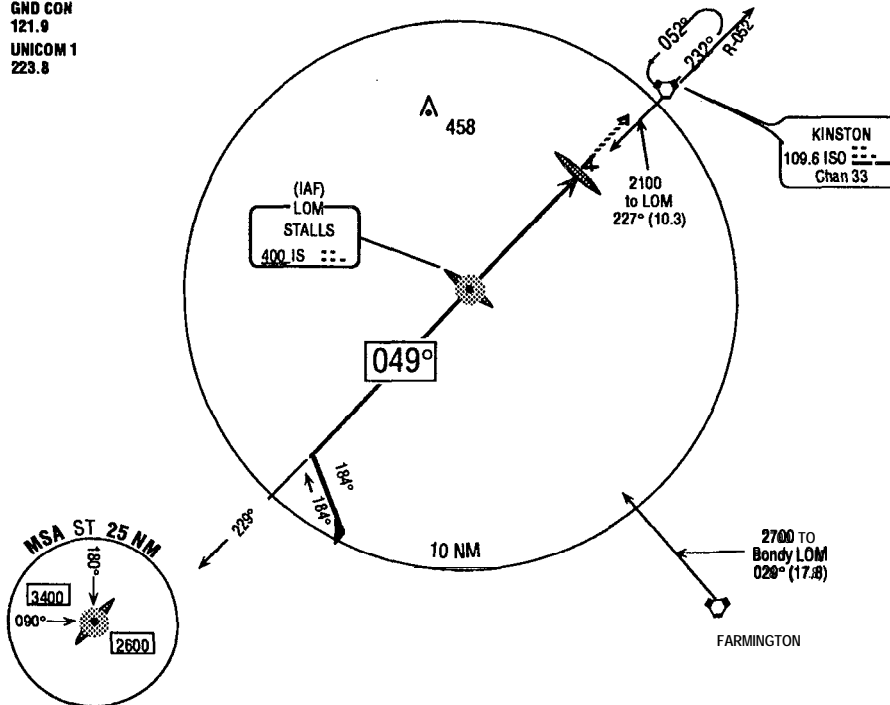
234

**Amdt 18**

# NDB RWY 4

**KINSTON/EASTERN REG. JETPORT AT STALLINGS FLD (ISO)**  
**AM565FAA KINSTON, NORTH CAROLINA**

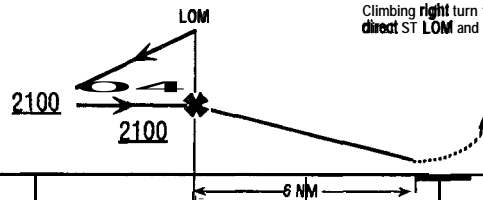
**SEYMOUR JOHNSON AFB CON**  
**119.738.6**  
**KINSTON TOWER**  
**128.6 (CTAF) 238.0**  
**GND CON**  
**121.9**  
**UNICOM 1**  
**223.8**



**Remain**  
within **10** NM

### MISSED APPROACH

Climbing **right** turn to **2700**  
**direct** ST **LOM** and hold.

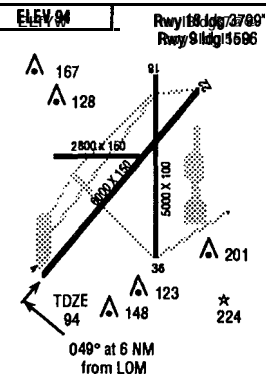


			6 MM	
CATEGORY	A	B	C	D
3-4	700-3/4	606 (700-3/4)	700-1 1/4 606 (700-1 1/4)	700-1 3/4 606 (700-1 3/4)
CIRCLING	700-1	606 (700-1)	700-1 3/4 606 (700-1 3/4)	700-2 606 (700-2)

**When control zone not in effect: 1. use Seymore Johnson altimeter setting. 2. Increase all MDA's 60 feet. 3. ACTIVATE MALSR Rwy 4C TAF.**



**NDB RWY 4**



REIL Rwy22

MIRL Rwy 18/36

764 A

FAF to MAP 5.9 NM

Knob	<b>69</b>	e
------	-----------	---

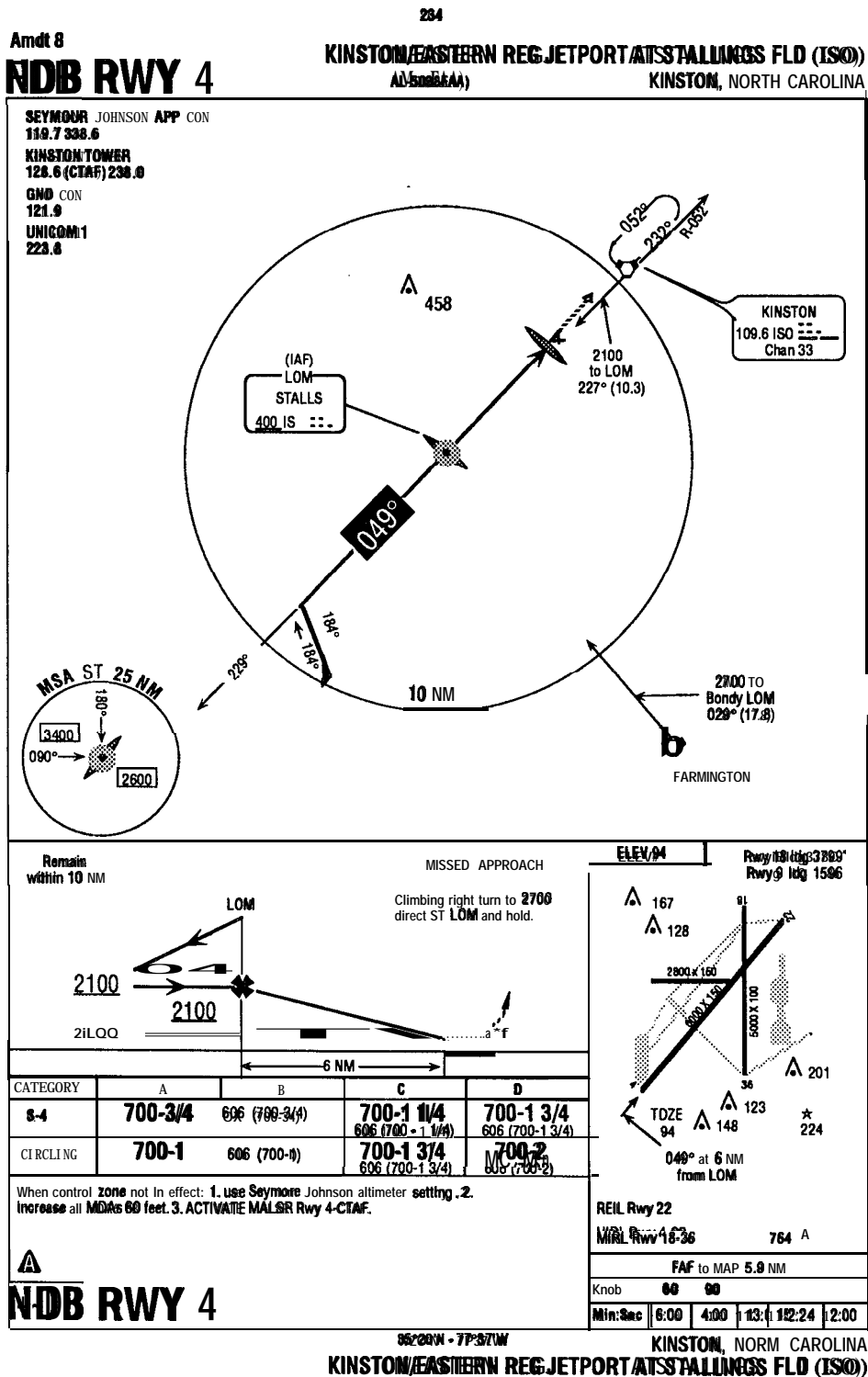
Min:Sec	6:00	4:00	1:30	12:24	2:00
---------	------	------	------	-------	------

35°20'N - 77°37'W

**KINSTON, NORTH CAROLINA**

**KINSTON/EASTERN REG JETPORT ATTS ALLINGS FLD (ISO)**

Font Size 12  
 Highlighting Reverse Video  
 Text Rotated





## **APPENDIX E: LAYOUT IAP TEMPLATES**

### Layout 1: Frequency below name

## Amelt 8

**NDB RWY 4**

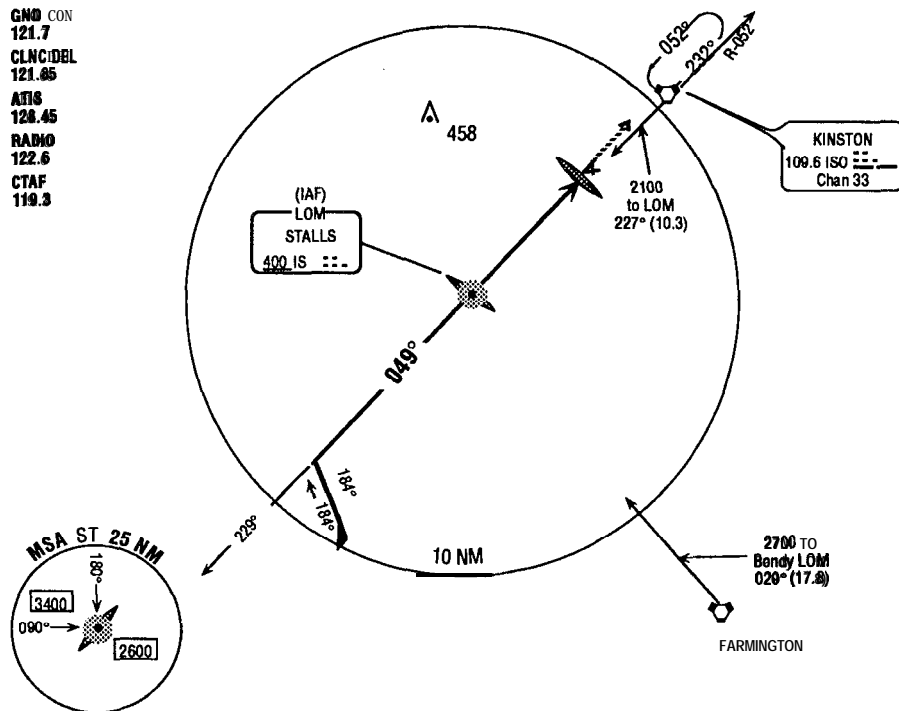
234

ISLIP/LONG ISLAND MACARTHUR (ISP)

AL-50355AA)

ISLIP, NEW YORK

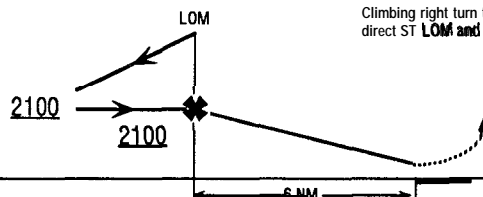
ISLIP APP CON  
120.5367.2  
ISLIP TOWER  
119.3233.2  
GND CON  
121.7  
CLNCIDEL  
121.65  
ATIS  
128.45  
RADIO  
122.6  
CTAF  
119.3



Remain  
**within 10** NM

**MISSED APPROACH**

Climbing right turn to **2700**  
direct ST **LOM** and hold.



CATEGORY	A	O	C	D
8-4	700-3/4	606 (700-3/4)	700-1 1/4 606 (700-1 1/4)	700-1 3/4 606 (700-1 3/4)
CIRCLING	700-1	606 (700-1)	700-1 3/4 606 (700-1 3/4)	700-2 606 (700-2)

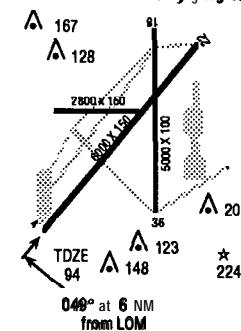
When control zone not in effect: 1. use Seymore Johnson altimeter setting. 2. increase all MDAs 60 feet. 3. ACTIVATE MALSR Rwy 4 CTAF.

**A**

# NOB RWY 4

ELEV 94

Rwy 18 ldg 3790  
Rwy 9 ldg 1506



REIL Rwy 22

MIL Rwy 18-36

764 A

FAF to MAP 5.9 NM

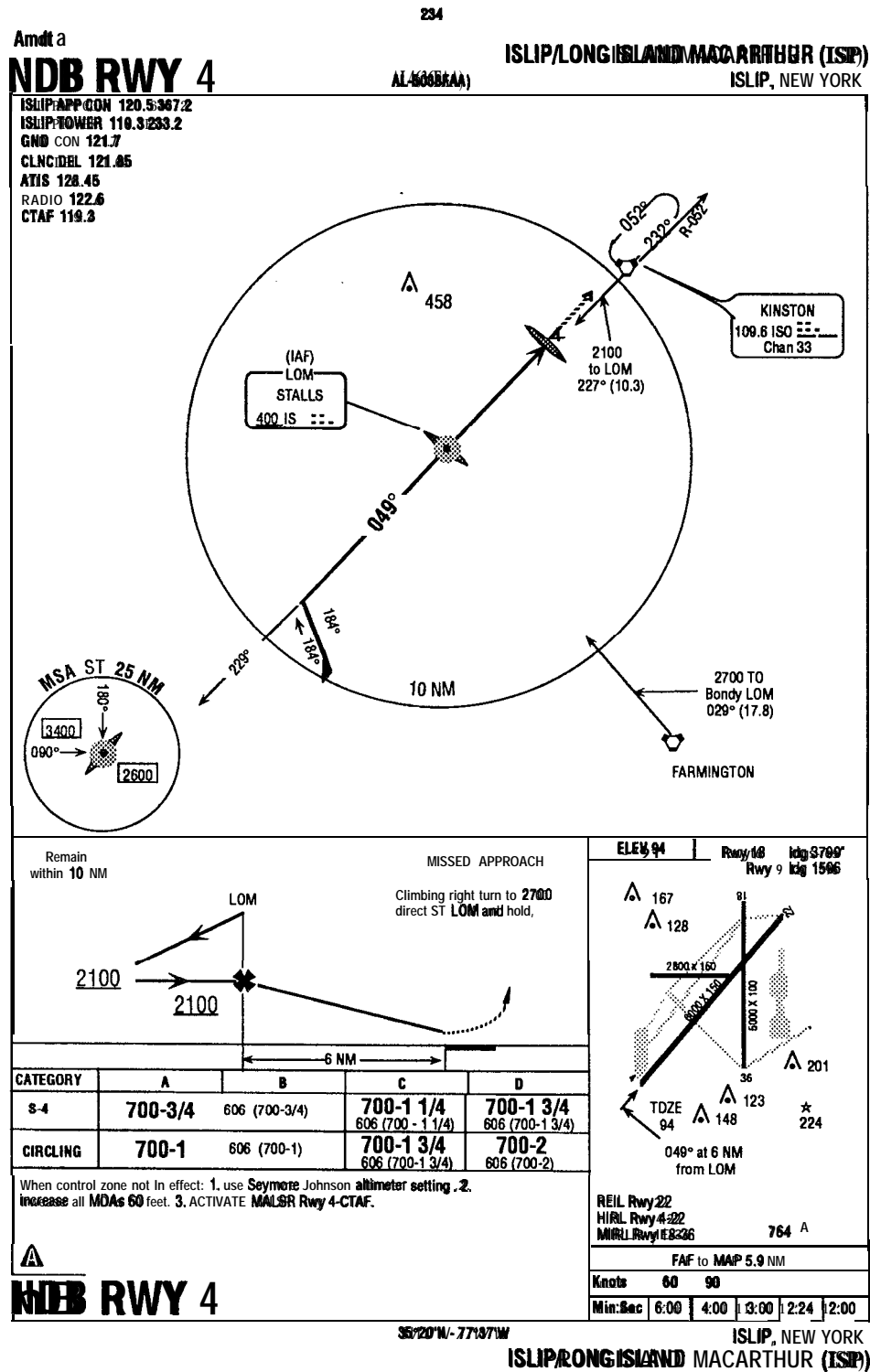
<b>Knots</b>	<b>60</b>	<b>to</b>	<b>120</b>	<b>150</b>	<b>180</b>
<b>Min:Sec</b>	<b>6:00</b>	<b>4:00</b>	<b>3:00</b>	<b>2:24</b>	<b>2:00</b>

**35°28'N - 77°37'W**

ISLIP, NEW YORK

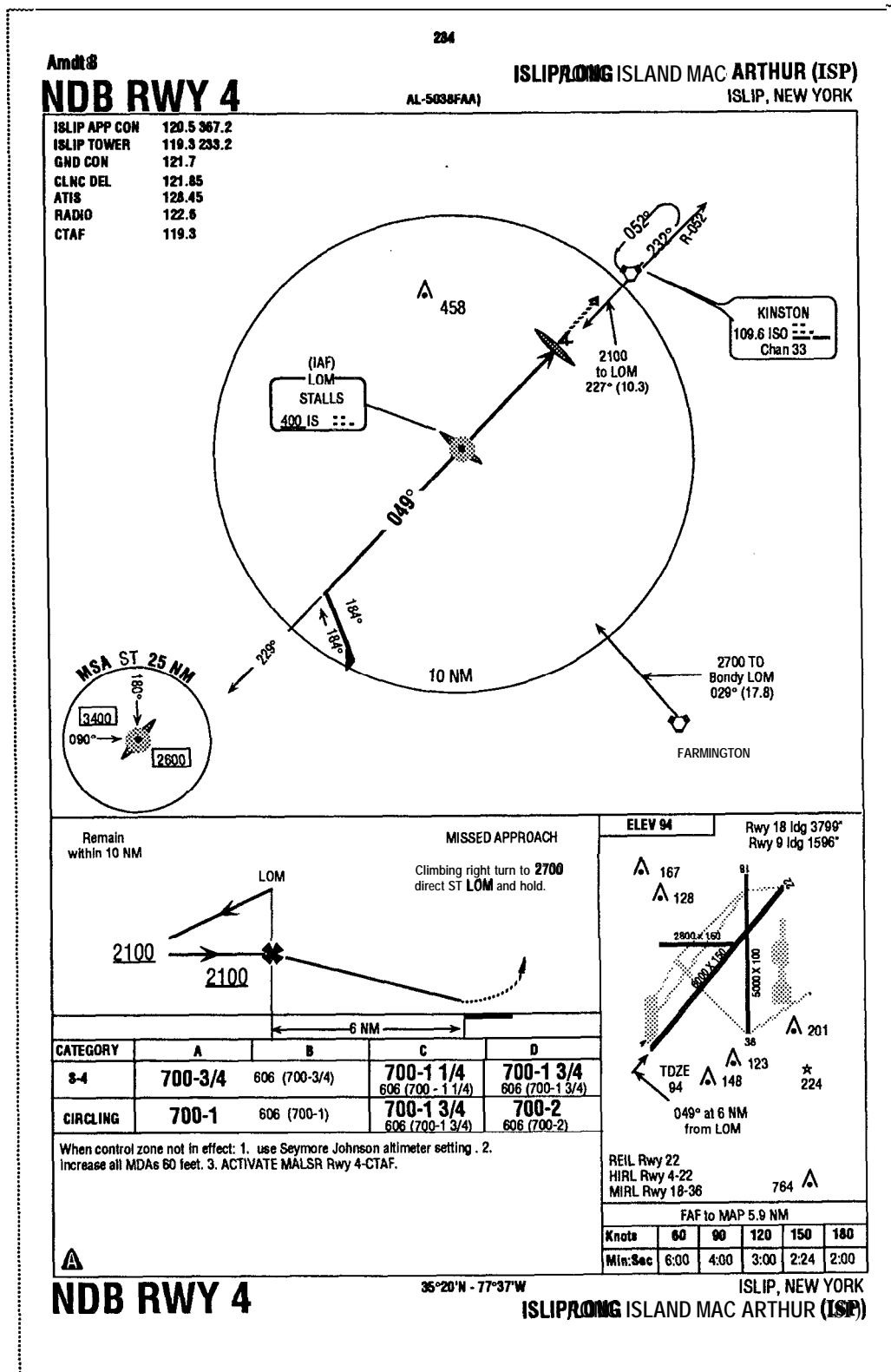
**ISLIP/LONG ISLAND MACARTHUR (ISP)**

## Layout 2: Frequency to the right of name

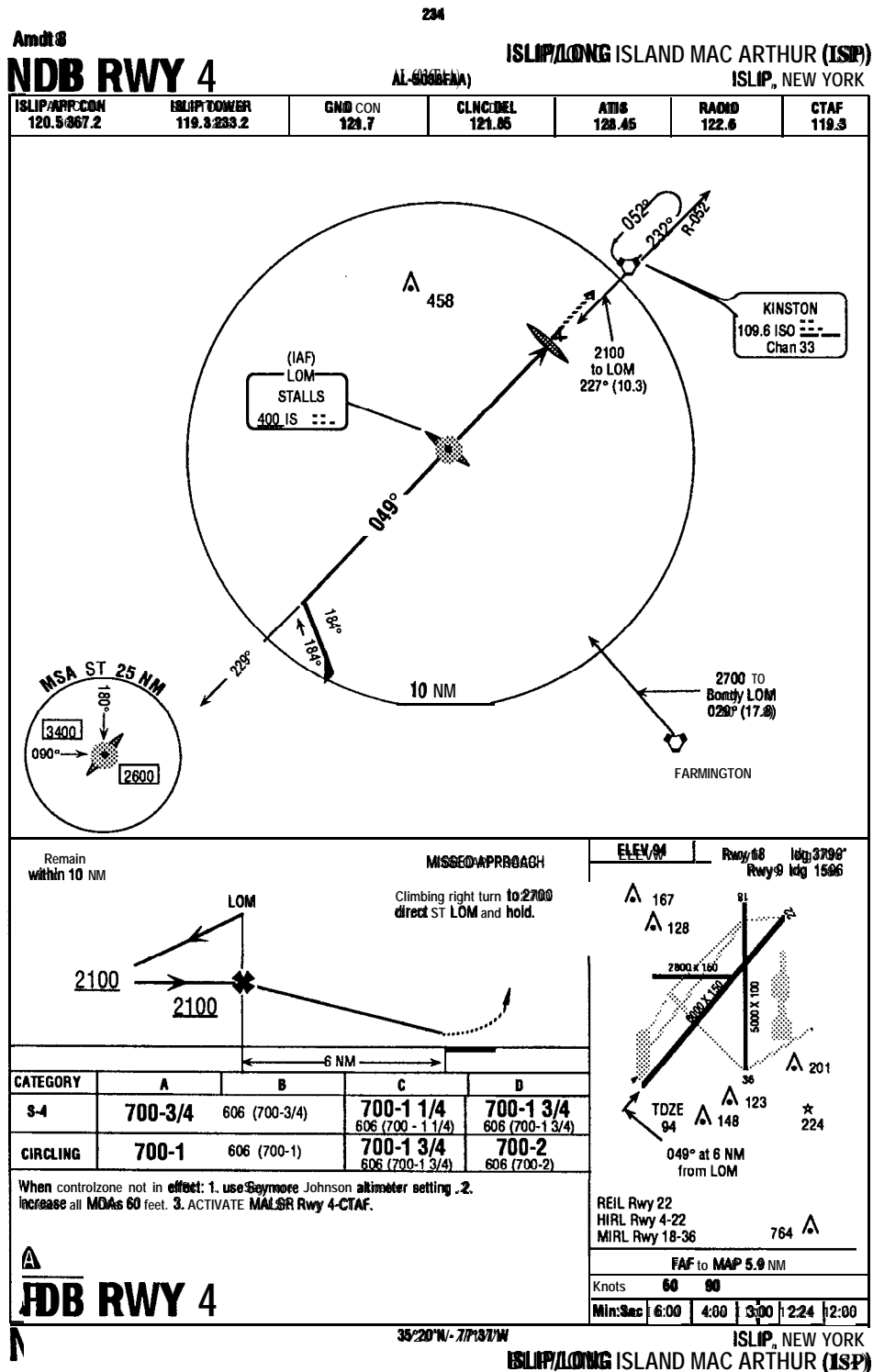




# Layout 3: Two column



# Layout 4: Boxed



## **APPENDIX F: CHART TEMPLATES**

# Chart 1: 1" off axis

Amdt 21

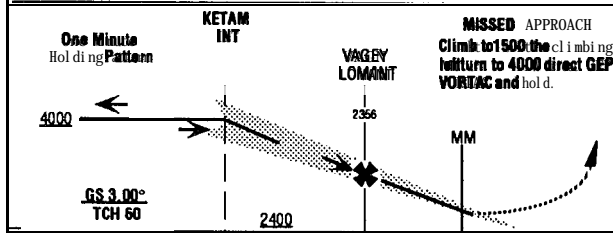
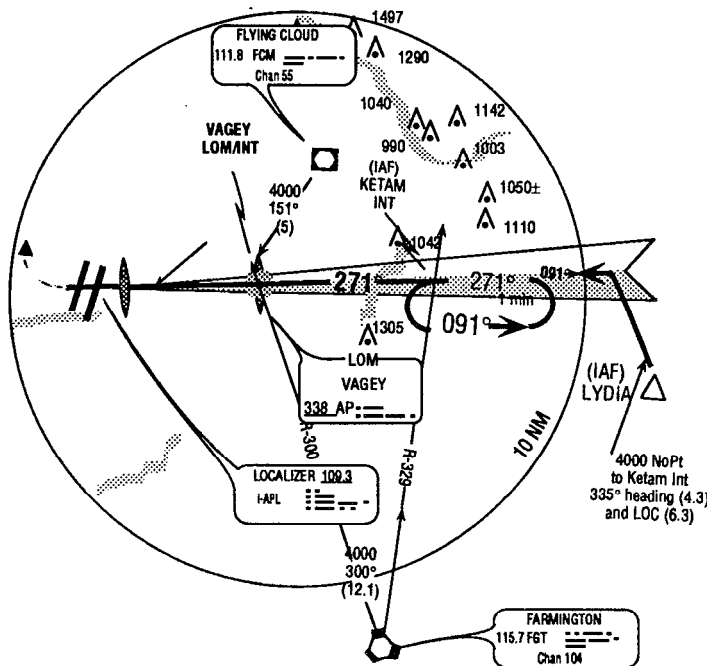
## ILS RWY 27

MINNEAPOLIS-ST PAUL INTL (WOLD-CHAMBERLAIN) (MSP)

AL-264 (FM)

MINNEAPOLIS, MINNESOTA

MINNEAPOLIS APP CON  
119.3 935.5  
MINNEAPOLIS TOWER  
126.7 257.6  
GND CON  
121.9 348.6  
CLNC DEL  
133.2  
ASR  
A318 335.35

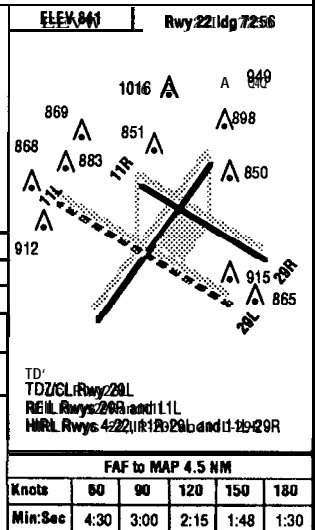


CATEGORY	A	B	C	D	E
3-ILS 27	1030/24	200 (200-1/2)	1260/40	1260/50	1800-3
S-LOC 27	1260/24 499 (500-1)	1260/40 430 (500-1/4)	1260/50 430 (500-1)	1800-3 959 (1000-3)	
CIRCLING	1340-1 499 (500-1)	1340-1 1/2 499 (500-1 1/2)	1460-2 610 (720-2)	1800-3 959 (1000-3)	

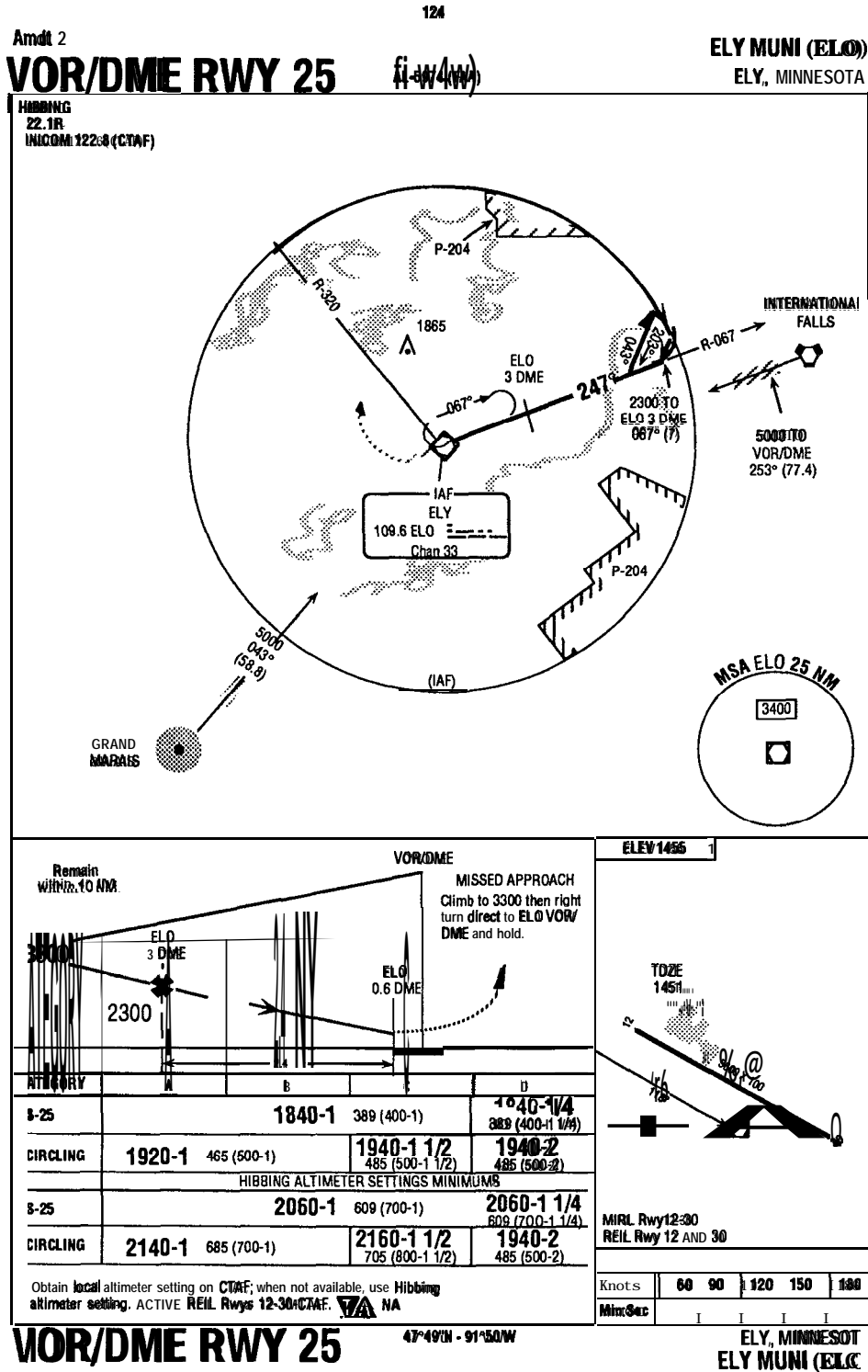


## ILS RWY 27

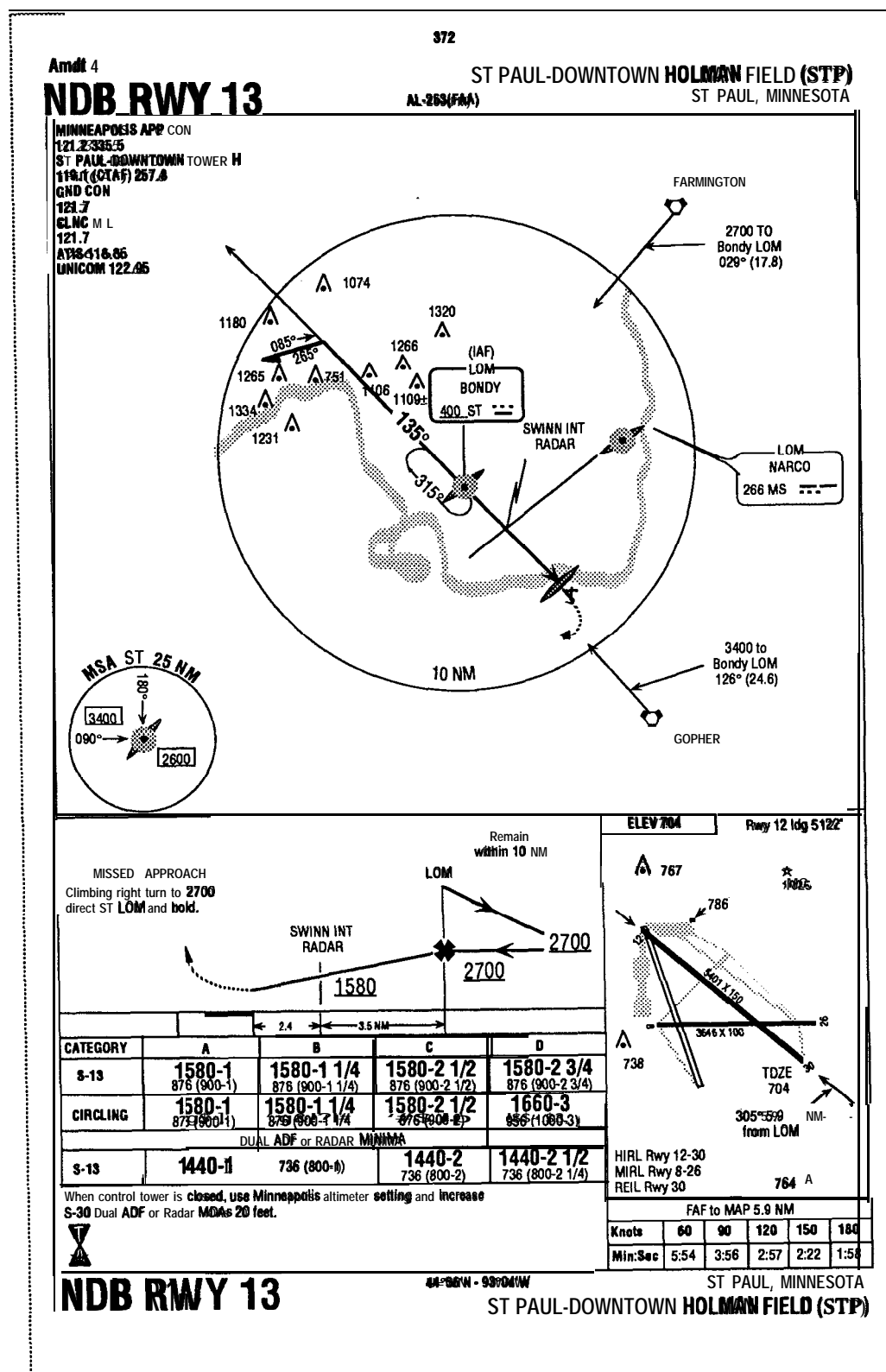
MINNEAPOLIS-ST PAUL INTL (WOLD-CHAMBERLAIN) (MSP)



# Chart 2: 23° off axis



# Chart 3: 45° off axis



# Chart 4: 63° off axis

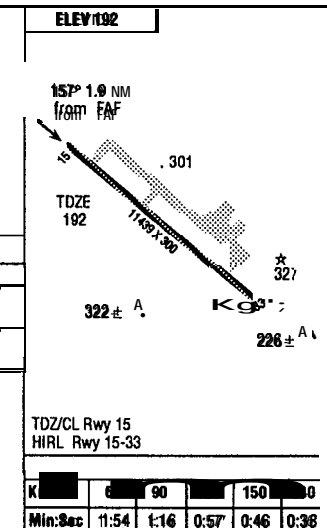
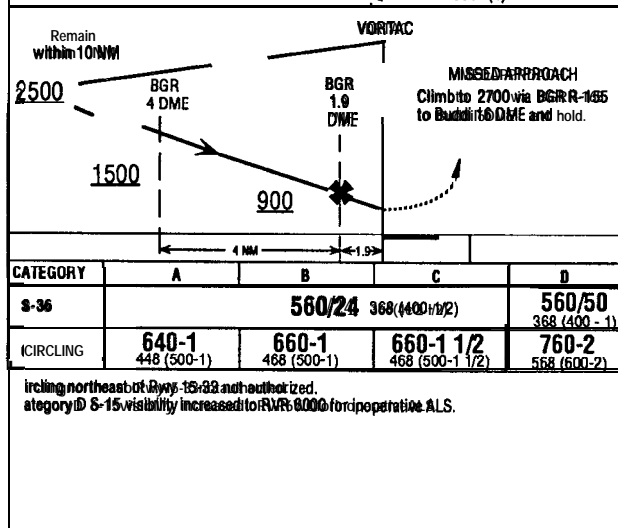
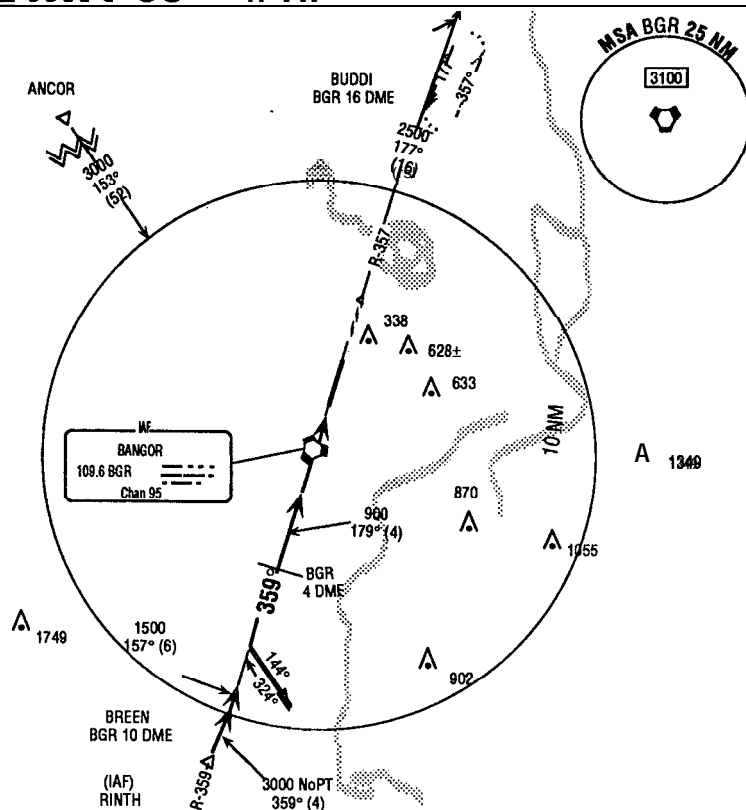
Amdt 3 88350

## VOR/DME RWY 36

44°48'N 68°50'W

BANGOR INTL (BGR)  
BANGOR, MAINE

BANGOR APP CONT  
124.5300.0  
BANGOR TOWER  
120.7257.8  
GND CON  
121.9348.6  
CLNC DEL  
121.9  
ATIS 127.75  
ASR

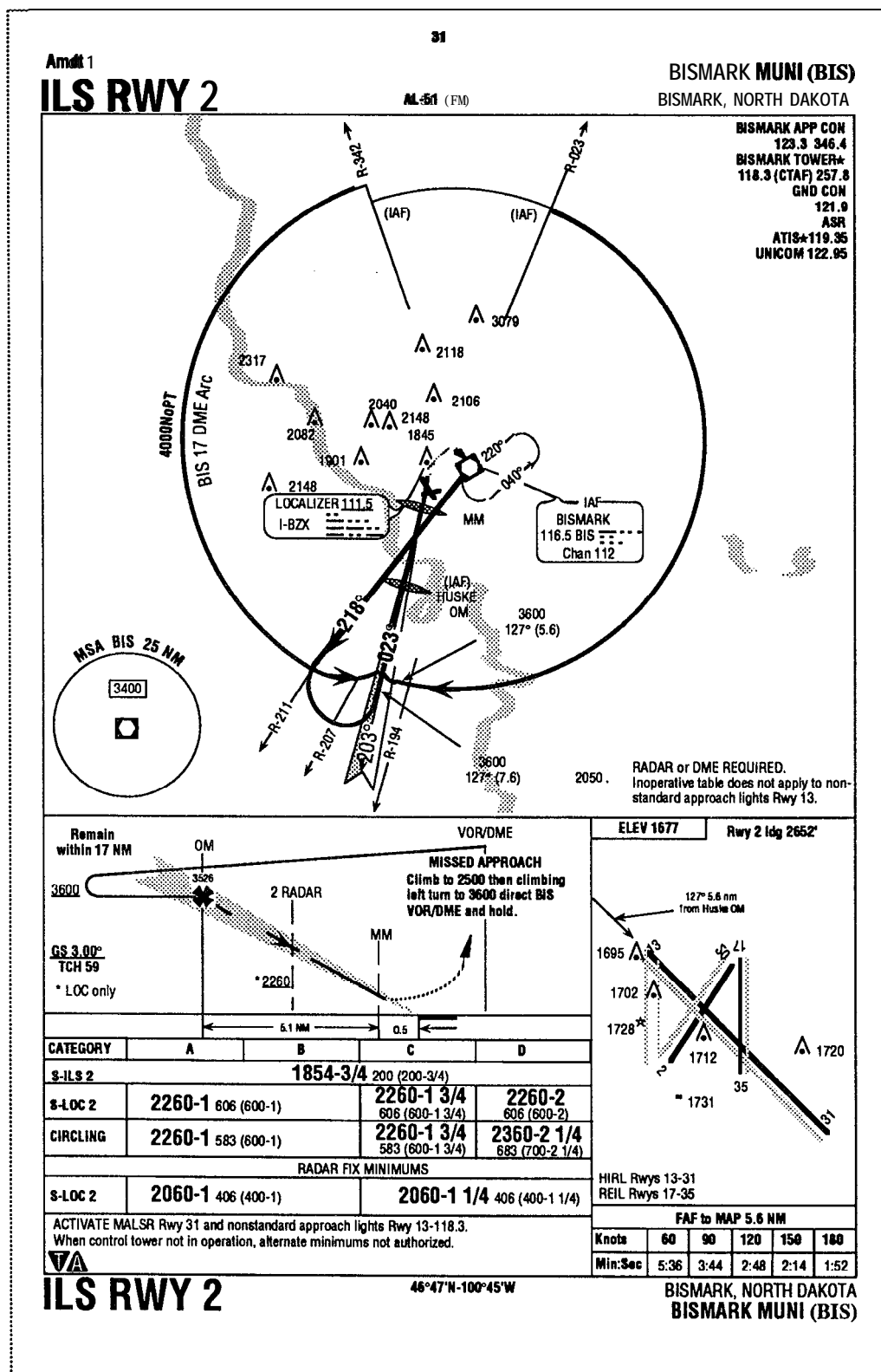


## VOR/DME RWY 36

44°48'N 68°50'W

BANGOR, MAINE  
BANGOR INTL (BGR)

# Chart 5: 67° off axis







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# Design Considerations for IAP Charts: Approach Course Track and Communication Frequencies

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